

1993

# Computer simulations, reflective journals, peer group interactions, and conceptual change about electricity with preservice teachers

Constance Phyllis Hargrave  
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**Computer simulations, reflective journals, peer group  
interactions, and conceptual change about electricity with  
preservice teachers**

Hargrave, Constance Phyllis, Ph.D.

Iowa State University, 1993

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Computer simulations, reflective journals, peer group interactions, and  
conceptual change about electricity with preservice teachers

by

Constance Phyllis Hargrave

Dissertation Submitted to the  
Graduate Faculty in Partial Fulfillment of the  
Requirements for the Degree of  
DOCTOR OF PHILOSOPHY

Department: Curriculum and Instruction  
Major: Education (Curriculum and  
Instructional Technology)

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**For the Graduate College**

Iowa State University  
Ames, Iowa

1993

This document is dedicated to my father, William J. Hargrave, Jr. whose life exemplified all this dissertation symbolizes- vision, determination, inner strength, and hope.

*"The difficulties I do immediately...  
The impossibles take me just a little longer."*

His spirit gave me the courage to achieve this goal, and his wisdom concerning life-long learning clarifies its meaning.

*"It's what you learn after you know it all that counts."*

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## ACKNOWLEDGEMENTS

It is with mixed emotions that the final steps of my doctoral program are completed. I am greatly relieved that the agonizing "paper" has reached its final version and that this part of my journey is at its end. However, there are some great advantages to being a doctoral student of which I am acutely cognizant as I turn this corner of my career. First and foremost, is the opportunity to try and to fail. Through the assistance of many ISU faculty members, I have had many chances to try. Many of my efforts have met with great success, and a number have met with great failure. But, most importantly I've had the chance to try, and as a result - to learn. Thank you Drs. Jackson, Volker, Thompson, Smaldino, Dilts, Andre, Netusil, Abbott, and Sternberg.

If a path has ever been paved that leads to the completion of a Ph.D. mine has been the yellow brick road and the Instructional Resources Center has been the Land of Oz. Thank you Jane, and all of the teaching and student assistants who have helped me along the way (especially Terry, Dawn, Kayt, Jodi, and Yuhsoon). A special thank you to Neal, Denise, Karen, Julie (Ham!) and Matt M. Although our interactions haven't always been ideal, I am grateful to Dr. Simonson who has stretched me intellectually and interpersonally. You kept your promise, Dr. S, I'm not the same person I was when I entered the program (and I'm sure you aren't either).

Not at all forgotten are those who helped ensure that I would complete this degree, including my life-long friend Deb (who often knows me better than I know myself), Patti (Pete), Andrea (Chu), and Jill J (you're fired!). I am especially grateful to Dr. Barton (Bubba) who saw potential and promise in me and gave me the opportunity to work at Ames Laboratory. In addition, Dr. Barton has provided financial and personal support to help me finish. Thanks Bubba.

Liz and Bob together are the original definition of "student support services". Liz has often been my cheerleader when I wasn't even in the game (or near the court). I am ever grateful to you for the friendship we've developed, for making me a part of your family, and for your endless support. Bob's non-judgmental disposition and subtle prodding have often been the

source of my inner runner's extra kick carrying me over the finish line again and again. You always provide an open ear and a good laugh. Thank you for your advice and friendship.

Last and most important, a heart-felt thank you to my immediate and extended family who provided me with a stimulating childhood and insisted that I follow my dreams. To my mother, whose peaceful strength and confidence has taught me to listen and to hear myself. To my sister Christine who faithfully stands rock-solid with her eye on the prize. To my brother Craig who has shown me how to laugh and to find strength in the moment of need; and to my brothers Carlon and Clayton who have insisted that I never settle for second best. I love you all.

## GENERAL INTRODUCTION

In the last fifteen years many studies have investigated the roles of prior knowledge and conceptions in students' abilities to learn science (Driver & Easley, 1978; Eaton, Anderson, & Smith, 1983; Barrass, 1984; Clement & Brown, 1984). Research in science education indicated that often traditional instructional practices are not effective in helping many students learn science concepts (Resnick, 1983; Mestre, Gerace, Hardiman, & Lockhead, 1987).

Because students entered into most formal science learning situations with naive theories of how various scientific processes operate, their existing conceptions interfered with their ability to learn new scientific concepts (McCloskey, Caramazza, & Green, 1980; Zietsman & Hewson, 1986). Assisting students in restructuring or altering their conceptions about various science domains may prove effective in facilitating learning in science.

The question investigated in this dissertation was "How can instruction that will effectively assist students in improving their conceptual understanding of science concepts be designed?". This dissertation was written in an alternate format that allowed for the inclusion of papers to be submitted to scholarly journals. It consists of two papers. The first is a review of the research that focuses on the nature of how science knowledge is developed. This paper reviews instructional approaches that incorporate how science knowledge is developed and how those approaches were effective in facilitating science learning. In addition, other potential instructional strategies to improve science learning are discussed. The second paper describes the study that investigated

the potential of computer-based instruction, reflective journals and peer group interactions to effect student learning about electricity.

### Explanation of the Dissertation Format

As was previously mentioned, this dissertation is written in a format that allows for the inclusion of papers to be submitted to scholarly journals. This is done in lieu of the chapter format but includes the same content. The references cited in the general introduction, the papers, and the conclusion are included after the conclusion. Material included in the appendices will not be submitted to scholarly journals as part of the papers.

**PAPER 1. CONCEPTUAL CHANGE-BASED INSTRUCTIONAL  
STRATEGIES TO IMPROVE LEARNING IN SCIENCE:  
A REVIEW OF THE RESEARCH**

## INTRODUCTION

This paper summarizes the results of research that focused on conceptual change-based strategies to improve student learning in science and indicates themes that suggest future directions for research in this area. Specifically, a review of the research on misconceptions in science learning is followed by a review of the theoretical foundation that supports a conceptual change approach to science instruction. Next, conceptual change-based instructional approaches that have been effective in improving science learning are reviewed. Finally, the potential of computer simulations and student journals as vehicles to implement conceptual change approaches to science learning are discussed.

## MISCONCEPTIONS IN SCIENCE LEARNING

The results of studies on science learning indicated that students entered into formal instructional situations with naive theories about some domains of science (Mestre et al., 1987; Zietsman & Hewson, 1986; Driver & Easley, 1978). Also called misconceptions, these naive theories have been observed and investigated in nearly every scientific field with a variety of topics, including: (a) heat (Erickson, 1979), (b) the particulate nature of matter (Novick & Nussbaum, 1981), (c) the earth as a cosmic body (Nussbaum, 1979), (d) light (Eaton et al., 1983), (e) photosynthesis (Roth, 1985b) and (f) the human body (Gellert, 1962; Porter, 1974; Quiggen, 1977; Deheny, 1978). The remainder of this section provides an overview of the nature of misconceptions, the development of misconceptions, and the influence of misconceptions in instruction, as documented in the literature.

### Nature of Misconceptions

Typically constructed from personal experiences and everyday observations, misconceptions about science are often fragmented, incomplete, and erroneous (Driver & Easley, 1978; Fredette & Clement, 1981; Eaton, Anderson, & Smith, 1987). Moreover, students' misconceptions interfered with their ability to learn new science concepts (Helm, Hugh, & Novak, 1983; Mestre et al., 1987). Because some science misconceptions are generally well developed, although erroneous, and appear to be supported by events in everyday life, they are very difficult to change (McCloskey, 1983; Arnaudin & Mintzes, 1985; Riley & Crocker, 1991). Summarizing several studies, Glover, Ronning, & Bruning (1990) reported that students' misconceptions tended to be very powerful so



much so that correct scientific conceptions observed in experimental settings may be negated by students and ultimately rejected.

In a study conducted with college freshmen enrolled in physics, Champagne, Klopfer, and Anderson (1980) investigated students' theories of gravity. Champagne et al. asked students to respond to the proposition "all other things being equal, heavier objects fall faster than lighter objects". The results indicated that nearly 80% of the students who participated in the study contended that heavier objects fell significantly faster than lighter objects. In another study investigating students' physics misconceptions, McCloskey and Kohl (1982) reported that students often viewed their own theories of science as superior to the abstract, and seemingly counter-intuitive principles of Newtonian physics.

### Development of Misconceptions

Naive theories about science develop naturally as each individual attempts to explain, rationalize, and understand the world (Resnick, 1983). For example, naive theories of photosynthesis were discovered in a study with elementary students; Roth (1985b) reported that some of the students believed that plants were living objects but did not need food.

McDermott (1984) considered the development of students' misconceptions as more than a set of false beliefs. Rather, McDermott suggested that often students developed uncoordinated and inconsistent conceptual systems concerning science phenomena. In contrast to McDermott, Blosser (1987) and Strike and Posner (1985) argued that students constructed well-organized, but incorrect conceptual systems. McCloskey (1983) stated that "people

develop remarkably well-articulated, naive theories of scientific phenomena on the basis of everyday experiences which provide them with casual explanations of how the world operates" (p.321). Although researchers differed in their interpretations of the development of students' misconceptions, they tended to agree that students' misconceptions about some domains of science effected their science learning in the classroom.

### Misconceptions and Instruction

Misconceptions influenced how individuals learn and think about science phenomena (Eaton, Anderson, & Smith, 1987; Mestre et al., 1987). Driver and Easley, (1978), Zietsman and Hewson, (1986), and Chambers and Andre (1991) reported that current evidence indicates students at all grade levels use pre-existing theories derived from previous experiences to reason about newly presented science concepts and to make sense of their instructional experiences.

Misconceptions in science were resistant to change even after instruction (Anderson & Smith, 1987; Driver & Easley, 1978; Fredette & Lockhead, 1980; Osborne, 1981; Champagne, Gunstone, & Klopfer, 1985b). In their investigation of college freshmen's theories of gravity, Champagne et al. (1980) found that not only did 80% of the students have misconceptions concerning gravitational pull on objects of various weight, but 70% of the students had studied physics in high school.

McCloskey et al. (1980) conducted a study to investigate college students' knowledge of classical physics. In the study, students were asked to predict the direction an object would move given the impact and force of other objects. The results indicated that even students who had taken high school physics gave

answers that showed naive conceptions of motion. Similar to the conclusions drawn from the gravity study conducted by Champagne et al. (1980), McCloskey et al. (1980) concluded that many students who had received traditional classroom instruction maintained naive theories of the physical laws of motion, force, and gravity.

Picciarelli, Di Gennaro, Stella, and Conte (1991) investigated the difficulties and common errors of college students in solving problems on circuit operations. The study, designed to generate explanatory data concerning students' misunderstandings of the flow of electric current within a simple circuit, used an eight item qualitative questionnaire to examine the persistence of misunderstandings.

The sample was composed of 236 sophomores and juniors majoring in physics or engineering. The students were divided into two groups: sophomores who had not had university-level, formal instruction on electrical circuits ( $N = 173$ ); and juniors who had received university-level, formal instruction on electrical circuits and had passed the university's physics examination for second year students ( $N = 63$ ). Approximately 40 percent of the sophomores ( $N = 74$ ) participated in a pretest before receiving formal instruction on electrical circuits. The entire sample took a posttest that was the eight-item qualitative questionnaire designed to elicit student explanations of current flow within simple electrical circuits.

The test answers were grouped into one of four categories: (a) Correct Answer with appropriate reasoning; (b) Sequential Reasoning (which the researchers defined as explanations based on the order in which current appeared to flow through a circuit); (c) Other Answers; and (d) No Answer.

The results of the study indicated that university students had conceptual difficulty explaining the behavior of simple electrical circuits. The data showed that traditional instruction had the greatest impact on those students who had weak misconceptions about current flow within a circuit (i.e., those sophomores whose answers were categorized as "Other Answer" or "No Answer" on the pretest). Thirty-seven percent of the sophomores whose answers were categorized in the Other Answer category on the pretest changed to the Correct Answer category on the posttest. Forty-two percent of the sophomores whose answers were categorized in the Other Answer category on the pretest changed to the Sequential Reasoning category on the posttest. Of the sophomores whose answers were categorized in the No Answer category on the pretest, 47% changed to the Correct Answer category on the posttest and 31% changed to the Sequential Reasoning category.

The results indicated that traditional instruction had little effect in changing the views of those who had strong misconceptions about current flow (i.e., those whose answers were categorized as Sequential Reasoning). The data showed that Sequential Reasoning misunderstandings were very resistant to change. Fifty-eight percent of the sophomores whose answers were categorized as Sequential Reasoning on the pretest maintained their perspective on the posttest even after receiving traditional instruction. Forty percent of the juniors who had received instruction on electrical circuits nearly one year prior to the exam, used Sequential Reasoning to interpret current flow.

Picciarelli et al. (1991) concluded that traditional instruction was somewhat effective in altering the conceptions of those with weak or no misconceptions about current flow within a simple electrical circuit, but was less

effective in altering the views of those who had strong misconceptions about current flow within a simple electrical circuit. To effect change in firmly held misconceptions, the researchers suggested that more dynamic instructional approaches may be more effective than lectures; they recommended that remedial activities based on pedagogical models that take into account students' misconceptions should be integrated into normal classroom activities.

Although effective for some students, traditional instructional strategies of presenting the scientific explanation of science phenomena in a lecture format do not effectively facilitate the acceptance of the scientific explanation by many students. The results of several studies indicated that informing students that their conceptual understanding of science phenomena was wrong or incomplete was not sufficient to permanently overcome most misconceptions (Resnick, 1983; Picciarelli et al., 1991).

## COGNITIVE PSYCHOLOGY, COGNITIVE INFORMATION PROCESSING, CONSTRUCTIVISM AND CONCEPTUAL CHANGE

To overcome students' science misconceptions, McDermott (1984) argued that the misconceptions must be unlearned before more accurate conceptual systems can be developed. To facilitate the unlearning of misconceptions, Mestre et al. (1987) suggested that formal educational processes need to become more bidirectional. That is, instructors must become more cognizant of their students' misconceptions, and these misconceptions must be openly addressed in the learning environment.

The development of many instructional strategies that openly address students' science misconceptions should be based on theories of student learning and cognitive psychology. The purpose of this section of the paper is to review the constructs of cognitive psychology that support a conceptual change theory of learning. A brief overview of cognitive psychology and a summary of contemporary research techniques used in science education are presented. In addition, cognitive information processing, constructivism, and conceptual change theory are discussed.

### Cognitive psychology and contemporary science education

A relatively young discipline, cognitive psychology attempts to explain behavior in terms of mental constructs (Gagne, 1985; Glover et al, 1990).

Cognitive psychologists define learning as an active process and suggest that teaching involves facilitating active mental processing by students (Gagne, 1985).

Contrary to behavioral theories of learning that consider the learner to be a passive recipient of information, cognitive psychology views the learner as an

active participant whose current conceptions influence the learning process (Driver, 1989; Phye & Andre, 1986). Moreover, cognitive psychologists suggest that learning consists of changes in mental structures brought about by reasoning and that new learning develops through the use of prior knowledge to understand new situations (Gagne, 1985; Phye & Andre, 1986). Because of its focus on the learner and on cognitive information processing, cognitive psychology appears to have powerful implications for improving student learning in science.

As models for understanding students' conceptual processes in particular science domains have evolved, so have the techniques used by researchers in science education. Studies conducted in the 1970s used interviews and other interpretive techniques to investigate and describe ways that students conceptualized science phenomena (Driver, 1989). Realizing that learning involved the structured organization of knowledge systems, researchers developed methods such as concept mapping and exploration of semantic networks to probe learners' knowledge structures (West & Fensham, 1974; Stewart, 1980; Novak & Gowin, 1984).

Current views of knowledge, knowledge development, and cognition theorize that specific mental procedures occurring in the mind direct the processing of information and manage the construction of knowledge (Driver, 1989). The cognitive information processing model and constructivism are interpretations of human cognition that support a conceptual change theory of learning.

### Cognitive Information Processing

A contemporary view of cognition, Cognitive Information Processing (CIP) attempts to develop precise, detailed models of human cognition; CIP views the mind as consisting of components used for processing information. In their model of CIP, Phye and Andre (1986) described five major components that comprise the cognitive system: (a) input buffers, (b) short-term memory, (c) long-term memory, (d) executive routine, and (e) output buffers. The movement of information through these components is the definition of thinking and learning to those who accept the CIP model (Phye & Andre, 1986).

Input Buffers are closely associated with the senses and hold incoming information for a very brief period.

Short-term Memory has a limited capacity and contains information that is currently being processed; information in short-term memory can be quickly lost if not transferred to long-term memory.

Long-term Memory is viewed as having a large capacity and being randomly accessible and content-addressable.

Executive Routine manages the flow of information processing and the allocation of mental resources for information processing.

Output buffers are those mental processes which monitor well-learned skills that operate without a great deal of conscious attention (Phye & Andre, 1986).

In the CIP model, learning is a product of the formation of relationships or associations between individual knowledge structures. Mental connections that develop between associations have been termed schemata; more precisely, schemata are frameworks of knowledge which collectively (through associations or linkages) represent individual units of self-contained knowledge (Norman,



1982). Learning, in the CIP model, also includes the development of new schemata. To fully understand learning as defined in the CIP model, one must possess a conception of knowledge and its development.

Nature of Knowledge. In contrast to behaviorists who view knowledge in terms of one's actions, cognitive psychologists believe that knowledge is at the core of human cognition and is the basis of understanding. Knowledge refers to the summation of one's experiences, perceptions and observations (Anderson, Spiro, and Montague, 1977). It consists of an organized set of mental structures and procedures (Phye & Andre, 1986).

Three types of knowledge are typically activated during the performance of complex cognitive activities: (a) domain-specific knowledge, (b) general knowledge, and (c) strategic knowledge (Glover et al. 1987). Domain-specific knowledge refers to knowledge that is required to perform a particular task. For example, to answer the question "if a lamp with a resistance of 4 ohms is connected to a 16-volt battery, what is the amperage?" requires a knowledge of types of electrical circuits, voltage, resistance, amperage, and Ohm's law.

General knowledge is knowledge that is used in a variety of tasks and is needed to guide the use of domain-specific knowledge. For example, the domain-specific task of measuring the parameters of electrical circuits requires general knowledge in the area of arithmetic in order to apply Ohm's law and complete the calculation.

Strategic knowledge is knowledge used to efficiently organize and apply general knowledge and domain-specific knowledge. For example, to answer the question about the measurement of current within a circuit, a student must decide the order of tasks that will best lead to the correct answer. The student

may decide that it is best to first analyze the kinds of circuits that may be involved (parallel, series, or simple), illustrate Ohm's law, and then perform the calculations.

Domain-specific, general, and strategic represent the types of knowledge students possess. In addition, these categories suggest how knowledge is applied in learning. The role students' existing knowledge and conceptions play in learning new information is of great importance in overcoming science misconceptions. Cognitive psychologists suggest that the organization of existing knowledge influences the development of new knowledge and the recall of knowledge.

Mental Organization of Knowledge. To understand how ones' current conceptions influence the acceptance of new conceptions, one must have an understanding of schemata. As previously stated, schemata are frameworks of knowledge which collectively (through associations or linkages) represent individual units of self-contained knowledge (Norman, 1982). Moreover, schemata are structures that represent bodies of information available to the learner and depend on the person's prior experience and knowledge of the world.

Knowledge is contained in structured frameworks called schemata. The schemata contain rules that relate individual concepts to each other and to the outside world. The rules for using schemata explain the relationships (or associations) between different units of self-contained knowledge structures. For example, a student's schemata of school may contain information about the physical characteristics of school, who is to be at school, when school is in session, and why schools exist. These isolated units of knowledge may relate to

his/her schemata of learning and rules related to where learning is to occur, when learning is to occur, types of learning, and the purpose of learning.

Schema theory suggests that knowledge is perceived, encoded, stored, and retrieved according to the slots in which it is placed. This appears to be consistent with the CIP model in which the mental representation of knowledge mirrors a relational database possessing many slots or storage locations for information; the CIP database is a hierarchically organized network of associations among schemata (Phye & Andre, 1986).

### Constructivism

Current perspectives on learning suggest that learning comes about through an individual's active involvement in knowledge construction (Driver, 1989). Because students' science conceptions have developed through personal experiences and observations over an extended period of time, students are unlikely to reconstruct or change their conceptions about science phenomena. However, if their current conceptions appear to be ineffective in solving a problem, dissatisfaction for the concept may develop within the student. When students are intellectually dissatisfied with their current conceptions, the likelihood of them restructuring their conceptions and accepting alternative conceptions increases (Posner, Strike, Hewson, & Gertzog, 1982). Constructivist theories of learning suggest that if instructional experiences illustrate how a new conception is more intelligible, plausible, and fruitful than the prior conception, student acceptance of the new conception may occur (Nussbaum & Novick, 1981; Strike & Posner, 1985). A constructivist model of learning and its relation to conceptual change is described next.

Learning, from a constructivist viewpoint, is an additive process of "sense making" in which the learner's conceptual schemata are progressively reconstructed to keep in line with a continually widening range of experiences (Noddings, 1990; Driver, 1989). Constructivists contend that learners use their perceptions, thoughts, experiences, and memory to build mental representations of the world; these mental representations (or schemata) are used to interpret new situations (Von Glasersfeld, 1989). Through processes of equilibration between knowledge and new experiences, learners are architects of their own learning. Educators who accept a constructivist view of learning, tend to agree that:

- All knowledge is constructed.
- Particular cognitive structures are activated during the processes of construction.
- Cognitive structures are under continual development.
- Cognitive constructivism implies pedagogical constructivism; that is, the acceptance of constructivist premises about student knowledge implies ways of teaching that acknowledge learners as active participants in knowledge development (Von Glasersfeld, 1990).

The constructivist perspective of learning mirrors Piagetian perspectives of learning in that it emphasizes the constructive development of knowledge structures on an individual basis. Solomon (1987) cited two significant differences between the contemporary constructivist perspective and Piagetian perspectives.

1. Contemporary constructivism emphasizes the development of domain specific knowledge as opposed to only the development of general logical capabilities emphasized by Piagetian viewpoints.
2. Contemporary constructivism emphasizes not only an individual's personal construction of knowledge through interactions with the physical environment, but also acknowledges the social processes that may occur in knowledge construction within a community of learners.

Driver (1989) cited the work of Vygotsky as being increasingly influential in shaping thinking about social and cultural influences on learning. "Learning science is seen to involve more than the individual making sense of his or her personal experiences but also being initiated into the 'ways of seeing' which have been established and found to be fruitful by the scientific community" (Driver, 1989, p.482).

Summarizing early investigations of students' conceptions about science phenomena, Driver (1989) argued that the results of such studies presented mere snapshots of the continual construction and reconstruction of students' knowledge. The insight gained from these studies does not provide information concerning the dynamics of the change processes involved in knowledge construction, information that is necessary for designing specific approaches to instruction.

The belief that student learning in science involves a process whereby an old theory is progressively replaced by a new theory has received a great deal of attention from science educators (Driver, 1989). In addition, this belief is a premise of the conceptual change theory of learning which attempts to explain how a person's current conceptions function in judging new ones by describing the conditions necessary for a major change in one's conceptions (Strike & Posner, 1985).

### Conceptual Change Model of Learning

The conceptual change model of learning was developed in the early 1980s as an approach to the application of constructivist ideas to science instruction (Driver, 1989; Hewson & Thorley, 1989). An overview of the Piagetian perspectives that support the conceptual change model is presented next.

Piaget (1964) proposed two phases that may occur when a student is engaged in schemata modification: assimilation and accommodation. According to Piaget, during assimilation students tend to interpret external events into their existing schemata, focusing only on the aspects of events that are relevant to their schemata. When students' schemata are challenged and questioned by disconfirming evidence or alternative viewpoints, a state of disequilibrium may occur. Disequilibrium motivates students to replace or reorganize their existing schemata, to defend their ideas, or to construct new schemata; this process is called accommodation.

Two fundamental principles support a conceptual change model of learning: Learning is a rational enterprise, and rationality is concerned with the conditions under which individuals are willing to change their minds. "The task of learning is primarily one of relating what one has encountered to one's current ideas" (Strike & Posner, 1985; p. 212). Thus, they contended that rationality has to do with how one moves from one viewpoint to another. In contrast to an empiricists approach to learning which does not consider the learner's current conceptual framework, a basic premise of the conceptual change model is that new conceptions are understood, judged, accepted, and/or rejected in a conceptual context; explaining learning, then, is primarily a matter of

explaining how this conceptual ecology functions for the student (Strike & Posner, 1985).

Posner, Strike, Hewson, and Gertzog (1982) developed a model of conceptual change based primarily on Piaget's (1964) assimilation and accommodation phases of the learning process. Using the term accommodation to refer to large-scale, holistic conceptual changes, and assimilation to refer to the kinds of learning where major conceptual revision is not required, Posner et al. (1982) proposed that four conditions must exist for an individual to acquire a new conception (accommodate).

1. The student must become dissatisfied with his/her current conception; he/she must experience the limitations of his/her current conception to solve the problem.

2. The new conception must be intelligible to the student; the student must be able to understand how the procedures of the new conception solve the current problem.

3. The new conception must be plausible; the new conception must be believable by the student as a method to solve the specific problem as well as related problems within the domain.

4. The new conception must be fruitful; the new conception must be practical in solving the problem in order for a student to adopt it.

Posner et al. (1982) used the phrase "conceptual change learning" to refer to the learning process that occurs when students' understandings and beliefs about a specific concept are restructured in a major way. Similar to Piaget's idea of accommodation and Vosniadou and Brewer's (1989) notion of radical

restructuring, the conceptual change model of learning describes the process whereby new information is learned only through challenging students' existing beliefs and conceptions and restructuring them.



## STRATEGIES TO FACILITATE CONCEPTUAL CHANGE

To explore the potential of the conceptual change model to effect student learning in science, researchers have developed instructional strategies that enable students to experience the four conditions necessary for conceptual change. In the following section, conceptual change-based instructional strategies are discussed. Specifically, modifications to science narratives and the technique of ideational confrontation, as articulated by Champagne et al. (1985a), are reviewed. In addition, the use of computer simulations and the potential of reflection and student journals to facilitate conceptual change about science concepts are discussed.

### Text Modification

To examine the effectiveness of a conceptual change model of learning, many researchers have modified the narrative of books and lessons. That is, traditional text explanations of science concepts have been redesigned to incorporate the four conditions of the conceptual change model in order to develop instruction that directs students to experience these conditions and change their conceptions (Driver, 1989).

Conceptual change-based modifications to traditional text tended to center on students' current conceptions about science phenomena (Hewson & Thorley, 1989). The purpose of this approach was to raise the status of the scientific conception in the mind of the student and lower the status of the student's misconception. In so doing, text designed for conceptual change attempted to make students aware of their own conceptions of a phenomena, illustrate the

limitations of their conception, and present and discuss the scientifically correct conception.

Investigating middle school students' misconceptions about photosynthesis, Roth (1985a) used the four conditions of conceptual change as articulated by Posner et al. (1982) to develop narrative on photosynthesis. The text material prepared by Roth (1985a) was redesigned to explicitly address middle school students' misconceptions about photosynthesis. A chapter from each of two commercially available textbooks and Roth's conceptual change designed text were used in the study that involved 18 students. After taking a pretest, the students were randomly assigned to one of three text groups (two commercial text groups and one conceptual change text). Over a period of three days, the students read the texts after which they received the posttest. In addition to the posttest scores, Roth conducted interviews with each student at the conclusion of each day. The interviews helped the researcher determine the reading strategy used by each student. Roth identified six reading strategies used by middle school students to interpret the text:

1. Overreliance on prior real-world knowledge.
2. Overreliance on isolated words in the text.
3. Overreliance on facts in the text (memorizing facts).
4. Separating disciplinary knowledge and real-world knowledge as two equally sensible worlds of knowledge.
5. Overreliance on prior knowledge to understand the disciplinary view of the text.
6. Use of text knowledge to change real-world ideas. (This is the correct strategy.)

Students in the conceptual change designed text group employed a reading strategy in which they used the information included in the text to alter their conceptions of photosynthesis. The results indicated that the conceptual change text caused students to become dissatisfied with their misconceptions of photosynthesis, introduced an alternative explanation the students could understand and believe, and showed that the new explanation was practical in explaining the processes of photosynthesis. The posttest scores indicated that those students who read the conceptual change designed text mastered a significantly greater number of scientific concepts about photosynthesis than those who read the material from commercial textbooks.

Similar to Roth, Wang (1991) and Carlsen (1989) modified traditional textbook narratives by incorporating a conceptual change approach to overcome students' misconceptions about electricity. Wang (1991) modified traditional text about electrical circuits by adding narrative that encouraged students to become conscious of their existing conceptions of current flow within electrical circuits. In addition, the narrative guided the students to explore the limitations of their conceptions and presented the correct conception.

In the conceptual change designed narrative used by Carlsen (1989), students were presented with illustrations of electrical circuits with light bulbs, wires, and batteries. Based on the four models of common electrical circuit misconceptions identified by Osborne (1983) and Shipstone (1984), some of the circuits were correctly configured to allow current to flow; others were not. In the narrative, the students were asked if, given the particular configuration of the circuit, they thought the circuit would work. This question was to encourage students to become aware of their beliefs about current flow within electrical

circuits. Next in the narrative, an explanation was provided explaining why the illustrated circuit worked or did not work. This explanation was to explicitly confront the students' misconceptions and cause them to become dissatisfied with their current beliefs about electrical currents.

After presenting several examples of circuits that would not work (each based on the common misconceptions identified by Shipstone (1984)), Carlsen presented a circuit that did work and the scientific explanation of why the circuit worked. After illustrating the inadequacies of the common misconceptions, Carlsen followed the steps of the conceptual change model and presented an intelligible and plausible explanation of why the circuit worked.

Modifying text as a method to facilitate conceptual change has been effective in assisting students in overcoming science misconceptions (Dole et al., 1991; Hewson & Thorley, 1989; Wang, 1991; Carlsen, 1989; Roth, 1985a). The effectiveness of this technique in permanently overcoming science misconceptions requires further investigation. Because of the complexity of some science content, variations of reading abilities, and other classroom contextual factors, additional methods to facilitate conceptual change in the classroom should be investigated (Hewson & Thorley, 1989; Driver, 1989). Ideational confrontation is a conceptual change strategy that has potential in the classroom environment (Guzzetti, Snyder, Glass, & Gamas, 1992); it is discussed next.

### Ideational Confrontation

Based on the Posner et al. (1982) model of conceptual change, Champagne, Gunstone, and Klopfer (1985a) developed and used a technique called ideational confrontation to alter misconceptions about motion held by middle school

students. Similar to investigations by Rogan (1988), Rollnick, (1988), and Hewson and Hewson (1983), ideational confrontation is a discussion-based approach to conceptual change. The technique of ideational confrontation, is initiated when students are asked to make a prediction about a phenomena. Each student is then directed to independently formulate and express an explanation that justifies and supports his/her prediction. Then, through group discussions, the students are encouraged to challenge each other's predictions and explanations in order to heighten the group's awareness of other perspectives and to affirm beliefs in individual perspectives.

After these discussions, the physical situation is demonstrated. Next, differences between what was observed in the demonstration and what students predicted are carefully noted. Encouraged by the teacher/facilitator to challenge the physical evidence, the students are led to the realization that their currently held conceptions are inaccurate. The correct scientific explanation of the physical situation is provided; this explanation is followed by discussions in which the students are encouraged to express similarities and differences between their conceptions and the scientifically accurate one. The goal of this final discussion and the entire technique, then, is to encourage students to realize the inaccuracies of their conceptions and accept the scientifically correct conception.

Champagne et al. (1985a) used the ideational confrontation technique with middle school students to investigate its effectiveness in assisting students in altering their misconceptions about gravity. In the study, the students were presented with two objects of varying weights and asked to predict which object would fall faster. Students were directed by the teacher to share their predictions and challenge the predictions of their peers. Many of the students predicted that

the heavier object would fall faster than the lighter one arguing that Galileo proved the fact the heavy objects fall faster. After the discussion, the teacher conducted the experiment by dropping the objects. When the blocks fell at the same rate the students argued that the blocks needed to be dropped from a greater height. When the blocks were dropped from a greater height they all fell at the same rate. The students then argued that the blocks weighed the same. Evidence was presented to verify the different weights of the blocks, and the experiment was conducted again and again until the students' reasons for why the blocks fell at the same rate were exhausted. The teacher then presented the scientifically correct explanation as to why the blocks fell at the same rate.

The results of Champagne et al. (1985a) indicated that ideational confrontation was an effective technique in assisting middle school students in altering their physics misconceptions. The effectiveness of the ideational confrontation technique should be investigated with students at various grade levels and in different domains of science.

### Computer Simulations

The use of computer simulations as a method to allow students to test their predictions has great potential for facilitating conceptual change (Zietsman & Hewson, 1986). It can be difficult to design and implement instruction to effectively overcome students' misconceptions about science because of classroom time constraints, scientific equipment and supply requirements, and the need to control variables. Recent developments in educational technology may enable the production of instructional environments that assist in overcoming specific science misconceptions. Computer simulations as a means

to facilitate conceptual change are discussed next. The review of the literature about computer simulations is followed by a review of the results of research in which a conceptual change approach was used with computer simulations.

Computer Simulations and Instruction. Technological advances in the last 25 years have resulted in the development of computer simulations that provide models of events or phenomena. In the physical sciences, simulations have been produced that allow users to test chemical equations (O'Haver, 1991), alter speed and motion variables (Hewson, 1983), and test hypotheses (Roschelle, 1991).

Computer simulations are used in many contexts in many disciplines; yet, within the context of instruction, the concept of simulations and their uses differ greatly. de Jong et al. (1991) identified key characteristics that distinguished instructional uses of computer simulations from other uses of computer simulations. Four characteristics defined instructional uses of computer simulations; they were:

Presence of a formalized, manipulable model A process, system or apparatus is formalized into a model and implemented as a computer program.

Presence of learning goals The simulation must be used to reach certain learning goals.

Elicitation of specific learning processes The simulation must be used to invoke specific learning processes characteristic of exploratory learning.

Presence of learner activity The learner must manipulate something in the simulation; this excludes situations where the simulation is used merely as a demonstration device.

The increasing sophistication and availability of microcomputers in recent years has led to the development and use of computer simulations in K-12 institutions. Computer simulations provided users with the means to manipulate variables and observe the effects of such manipulations in an environment that may not be possible, practical, or feasible any other way (Dekkers & Donatti, 1981; Rivers & Vockell, 1987).

Computer simulations can present environments that involve students in problem solving, critical thinking, and analytical reasoning. For example, the Factory is a computer program designed to develop problem solving skills. In the Factory lesson, a two-dimensional object appears on the screen. The object may have lines stretching diagonally across it and/or two or three holes lined top to bottom punched through it. The student's task is to analyze the object and organize and order procedures in the factory that will produce another object with the same features. Decisions that students must make in order to produce the object include: (a) the number of lines or punches the object receives, (b) the angle at which the object should be when it receives its lines and punches, and (c) the kinds of lines and punches the object should receive.

Dekkers and Donatti (1981) gave several reasons for the use of simulations in instruction: (a) improvement of motivation, (b) enhancement of cognitive learning of factual information, (c) improvement of critical thinking skills, and (d) improvement of the transfer of learning to other situations. Rivers and Vockell (1987) argued that in comparison to traditional laboratory settings, computer simulations allowed students to solve problems more efficiently because computers perform time-consuming peripheral tasks (such as tabulating data).



The ability of computer simulations to provide controlled settings in which to manipulate data also was perceived as an advantage over traditional laboratory experiences (Rivers & Vockell, 1987). Traditional laboratory experiments can produce data tainted with measurement errors. Rivers and Vockell (1987) suggested that as students are learning the processes of science and are becoming more familiar with the nature of the variables, it may be difficult to establish relationships or testable hypotheses under uncontrolled conditions. They argued that the use of computer simulations can provide students with the level of control needed until they become more comfortable with the processes of science.

Computer simulations have been developed and used to facilitate conceptual change by several researchers (Zietsman & Hewson, 1986; White & Frederiksen, 1987; Carlsen, 1989). The results of these studies are discussed next.

Computer Simulations and Conceptual Change. In a 1980 study investigating students' conceptions of velocity, Trowbridge and McDermott constructed a physical model to identify students' misconceptions about the concepts of velocity and position. The model, designed to demonstrate the differences between velocity and position, could repeat the relative motion of two balls on a sloping rail an unlimited number of times. The researchers reported that the model was effective in identifying students' misconceptions concerning the differences between velocity and position.

Based on the work of Trowbridge and McDermott, Hewson (1985) developed a computer simulation to perform the same diagnostic test as the Trowbridge-McDermott physical model and identify students' misconceptions of velocity and position. Results of the study implied that instruction provided by

microcomputers on an individual basis was effective. Specifically, the microcomputer simulation of the Trowbridge-McDermott model generated the same results as the physical model and was just as effective but more efficient in diagnosing students' physics misconceptions.

In a follow-up study, Zietsman and Hewson (1986) investigated the effectiveness of the computer simulation in comparison to the Trowbridge-McDermott physical model to diagnose students' misconceptions about velocity. In addition, they included a remediation component to the computer simulation to provide instruction based on the students' diagnosed misconceptions. Using a conceptual change approach, the remedial instruction components produced significant changes in students' conceptions of velocity. That is, the conceptual change-based computer simulation was significantly more effective in overcoming misconceptions and facilitating the acceptance of scientifically correct conceptions of physics than traditional instructional strategies. The results of the study indicated that computer-based science instruction that employed conceptual change strategies was effective in addressing velocity misconceptions.

Computer simulations about electricity have been used to allow students to build circuits and trouble shoot the effectiveness of the circuits. White and Frederiksen (1987) examined the effectiveness of a simulation entitled QUEST. Its purpose was to overcome students' misconceptions about electrical circuit operations. An intelligent simulation, QUEST was designed with knowledge of functional and structural properties of an electrical circuit. To help students solve problems with electrical circuits, the QUEST program had the capability of monitoring changes in the electrical circuits, altering the state of each circuit

component based on the change in the circuit, and providing students with causal qualitative explanations of the circuits.

Before receiving instruction via QUEST, the seven high school students in the study were given a pretest to assess their misconceptions of electricity. The results of the pretest indicated that all seven students possessed serious misconceptions about circuit operations and lacked basic knowledge about electricity. The students, who prior to the study had received no formal instruction about circuits, worked individually with QUEST for a total of five hours over five days. After working with QUEST, each student was able to make accurate predictions about circuit operations and behaviors and effectively troubleshoot series circuits. White and Frederiksen (1987) contended that it was paramount for students to learn about the qualitative aspects of circuits before they could properly apply formulas for resistance and voltage.

In another study about electricity, Carlsen (1989) investigated the effectiveness of a computer simulation along with conceptual change designed text to overcome undergraduate students' misconceptions about electric circuits. Using a 2 X 3 factorial design study, Carlsen examined text type (conceptual change text versus traditional text) and use of a computer simulation (before instruction, during instruction, and no simulation). The results indicated that using the simulation and the text designed to promote conceptual change was significantly more effective in overcoming misconceptions about electric circuits than using the text without the simulation. Moreover, the use of the conceptual change designed text was more effective in overcoming common incorrect misconceptions about electric circuits than was the traditional text.

The literature on computer simulations and instruction indicates that computer simulations can enhance science instruction. Computer simulations enable students to test hypotheses and receive science instruction that is not practical, feasible, or possible in typical classrooms (Dekkers & Donatti, 1981; Rivers & Vockell, 1987). The results from studies that have combined computer simulations and conceptual change-based instruction suggest that the use of these techniques can effectively assist students in altering their misconceptions about science (Zietsman & Hewson, 1986). Moreover, conceptual change-based computer simulations appeared to be more effective in overcoming misconceptions than traditional instructional approaches (Carlsen, 1989).

### Reflection and Student Journals

Many cognitive psychologists purport that the purpose of active learning is to engage students in cognitive processes and thus facilitate their construction of knowledge. Reflection is one technique that can heighten student's awareness of cognitive processes. In this section the concept of reflection is discussed as is the use of student journals as a method to encourage reflection.

Used often in the professional preparation of teachers and education administrators, reflection has been defined as "making knowledge which is normally tacit more explicit" (Hewson, Hewson, & Jensen, 1989; p.4); "Reflection is integration of knowledge with action through thought" (Hart 1990, p. 222). Kottkamp (1990) interpreted reflection as a cyclic process of paying deliberate, analytical attention to one's actions in relation to intentions in order to make conscientious decisions about improved ways of acting in the future.

Summarizing the role of reflection on learning, Dewey (1933) argued that students do not actually learn from experience alone as much as they learn from reflecting on experience. Dewey (1933) interpreted growth as the combination of experience and reflection: "Experience with no reflection is shallow and at best leads to superficial knowledge" (p. 20). Dewey (1933) defined reflective thinking as the process of mentally reviewing a subject and giving it serious, consecutive consideration. Reflective thinking, Dewey insisted, liberates an individual from performing impulsive and routine activity, enabling him/her to act deliberately and intentionally to achieve his/her goals.

Writing can be a powerful medium for learning and a powerful means of facilitating reflection (Posner, 1985). Emig (1977) suggested that writing was both process and product. Kottkamp (1990) viewed writing as an active, engaging, personal process and stated that writing was self-produced feedback, available for immediate review and evaluation of ideas. Additionally, because of its slow, self-regulating pace, writing allowed one to move back and forth among past, present, and future.

Kottkamp (1990) contended that writing was often a reflective process in itself. He noted that authors typically would pause, reread and rethink the very descriptions and ideas they were in the process of formulating and inscribing; moreover, when writing was done by the one reflecting, it provided a self-perspective on events that could be compared with viewpoints on the same events that were generated in other ways.

Because they are adaptable in form and purpose, journals, as a means of reflection, have been used in a variety of educational environments (Fulwiler, 1987). In a preparation program for school superintendents, Schmuck (1988)

used what he termed Learning Journals. He defined Learning Journals as loosely structured writing books for focusing thoughts about practice.

Barnett and Brill (1989) used two kinds of journals in a program to prepare elementary and secondary school principals: the Daily Journal and Critical Incident Journal.

Used during the internship component of their program, the Daily Journal was a continuing account of events and interactions of concern to administrators, teachers, and students. More focused and structured than the Daily Journal, the Critical Incident Journal was used to document selected, significant experiences in great detail. Barnett and Brill (1989) provided students using the Critical Incident Journal with a common format that included five sections: (a) a brief summary description; (b) important questions generated by events; (c) list of new jargon or concepts; (d) subjective reactions to the incidents; (e) description of what was learned and how it might alter future responses.

To encourage education majors to critically analyze classroom behaviors, Kottkamp (1990) developed and used Stop Action Journals with preservice teachers. Stop Action Journals were used during classroom activities in which student actions were literally stopped at various points during simulations and role plays. The students were then asked to reflect in their journals what had just occurred.

Kottkamp (1990) used Stop Action Journals throughout instructional events. For example, prior to a role play, students might be asked to record their intentions for action, what they wished to accomplish, and how they would accomplish their intentions. At the conclusion of the role play and before any discussion, the class was directed to document events or behaviors of the role

play in relation to previously stated intentions. At times, reflection through the use of the journals was used after the discussion; other times it may be before and after discussions. Kottkamp reported that the stop action form of his journal legitimized classroom time for reflection, making it as important as traditional sharing through discussions. In addition, he reported that journals provided him with information about how students perceived various instructional situations and made his students more aware of their own thought processes.

The power of reflective writing as a means to facilitate the improvement of student learning in science has not been fully explored. Moreover, few studies have been conducted that examine the effects of student journals on science learning. Malachowski (1988) incorporated the use of student journals in a chemistry course and investigated the effect of journals on student understanding. The major purpose for the journals was to help students improve their ability to formulate ideas. By emphasizing the process of writing, Malachowski reasoned that writing was a means of self-discovery.

In the chemistry course for non-chemistry majors, students were asked to make regular entries in their journals. The student journals had four sections. These were:

1. Scientific observations made outside of class - for writing outside of the regular class period, this section was used to augment the textbook or to introduce new topics.
2. In-class prompts - students were directed to document their thoughts prior to discussion or immediately after a presentation (Occasionally they wrote before and after the topic; thus, students had the chance to process the information and comment on their newly acquired knowledge.).

3. Observations and analyses of classroom experiments - Students were asked to record what they observed in each classroom presentation as if they were performing the experiment themselves.

4. Responses to other students' writings.

Malachowski's (1988) observations about this strategy suggested interesting possibilities for science education. After the semester-long course, Malachowski reported many students stated that they had gained additional insights into various chemistry topics by writing about them and having to think them through.

Malachowski (1988) noted that students became immediately involved because of the freedom and latitude given them to write on their own about a scientific topic. Malachowski reported that having students describe in their own words what they observed and the significance of their observations was an efficient way to use journals and one that seemed to increase student understanding immensely.

Finally, Malachowski (1988) indicated that because the use of journals in class was time consuming, some topics could not be covered as deeply as they typically would. Overall, however, Malachowski stated that the depth of student involvement and their demonstrated understanding of science suggested that the students might retain their knowledge of chemistry over extended time periods.

Many researchers and educators have suggested that instructional processes must become less didactic in order to overcome misconceptions and facilitate conceptual change (Posner et al., 1982; Resnick, 1983; Champagne, Gunstone, & Klopfer, 1985a; Mestre et al., 1987; Picciarelli, 1991). They suggested



that teachers needed to be made more aware of students' conceptions before, during, as well as after instruction in order to guide their learning. In addition, students needed to become more conscious of their knowledge structures. The use of student journals as a means of encouraging reflection was one method that helped students focus on their conceptions.

## SUMMARY

The presence of student misconceptions about topics in science education is well documented. The literature indicates that students use their conceptions, as well as their misconceptions, to reason about new concepts. Moreover, their misconceptions tend to be resistant to change. The development of instructional strategies that confront student misconceptions and facilitate the acceptance of scientifically correct conceptions may improve student learning.

Cognitive psychology indicates that students' schemata influence how they process new information. Moreover, cognitive psychology suggests that students must be active participants in learning and that instruction must take into consideration existing conceptions. The conceptual change model of learning attempts to explain how a person's current conceptions function in judging new conceptions by describing the conditions necessary for a major conceptual change.

Text modification and ideational confrontation are instructional strategies that have been effective in facilitating conceptual change and altering students' misconceptions about science. In addition, computer simulations have been effective in facilitating conceptual change. Literature on reflection and student journals suggests that writing, as a means to engage students in the processes of conceptual change, may have great potential. Future research should examine the effectiveness of coupling these instructional strategies to encourage long-term conceptual change of students' conceptions in various domains of science.

**PAPER 2. EXAMINING THE USE OF COMPUTER SIMULATIONS,  
REFLECTIVE JOURNALS, AND PEER GROUP  
INTERACTIONS TO FACILITATE CONCEPTUAL CHANGE  
ABOUT ELECTRICITY**

## INTRODUCTION

Developing instructional strategies to alter students' misconceptions about scientific concepts may significantly enhance science education. In this paper the results of a study that investigated the effectiveness of computer simulations, reflective journals, and peer group interactions to assist students in altering their conceptions about electricity are reported.

### Misconceptions in Science

To understand the world around them, students often develop naive theories (or misconceptions) about natural phenomena (Helm, Hugh, and Novak, 1983; Driver & Easley, 1978; Eaton, Anderson, & Smith, 1983; Mestre, Gerace, Hardiman, & Lockhead, 1987). The existence of these misconceptions in science learning is well documented (Helm, Hugh, and Novak, 1983; Driver and Easley, 1978; Osborne 1983; Osborne and Freyberg, 1985; Novak, 1987). Such misconceptions about science concepts are deeply seated and difficult to dislodge (McDermott, 1984; Resnick, 1983). For example, McCloskey, Caramazza, & Green (1980) asked college students to predict the direction an object would move given the direct impact of another object. Even students who had taken high school physics classes retained naive conceptions of motion. Similar conclusions about scientific concepts were drawn by Champagne, Klopfer, & Anderson (1980). These results suggest that even students who have received instruction maintain naive theories about scientific concepts.

Electricity and electrical energy are basic science concepts commonly discussed in the upper elementary (grades 4-6) science curricula. Often, these concepts are covered (in greater depth) in junior and senior high school and

college science courses. While much of the research on misconceptions about physics has focused on mechanics, numerous studies have investigated their role in electricity.

### **Electricity and Student Conceptions**

Summarizing the results of several studies investigating students' understanding of electrical circuits, Picciarelli, Di Gennaro, Stella, & Conte (1991) concluded that students from various academic levels possess common misconceptions about electricity. Fredette and Lochhead (1980) found that more than 30% of freshmen engineering majors indicated that only one connection between a battery and an electrical device was needed to make a device operational. Osborne (1983) found similar results with elementary children; 50% stated that only one connection between a battery and an electrical device was needed to make a device operational.

Misconceptions about series circuits appear to form a developmental sequence. Shipstone (1984) identified a developmental sequence of four models and Osborne (1983) identified one model of students' thinking about current flow in electrical circuits. These five models were:

1. Sink model A single wire connecting an electrical device and a power source can make the device operational; electric current does not return to the battery.
2. Clashing current model Current from the positive terminal of a power source moves through the wire toward an electrical device. Current from the negative terminal of the power source moves through the wire toward an electrical device; both currents meet at the device and clash, thus causing the device to work.

3. Unidirectional without conservation model Current flows in one direction from the power source around the circuit and back to the power source. As the current flows around the circuit, it is consumed by each device encountered thus becoming weaker until the current has been drained from the power source.

4. Unidirectional with equal sharing of current model Current flows in one direction from the power source around the circuit and back to the power source. Each device in the circuit shares the current equally and consumes part of it so that less current returns to the power source than originally leaves.

5. Scientifically correct model Constant current flows in one direction through the circuit, it is shared equally among the devices in the circuit and is not consumed.

The persistence of misconceptions about electrical circuits was investigated by Picciarelli et al. (1991). The researchers asked college students who had not received university instruction about electrical circuits to explain the process of current flow within an electrical circuit. Before receiving university instruction, 60% of the college sophomores based their explanations on the order in which current appeared to flow through a circuit; this common misconception is called sequential reasoning. Immediately following instruction, 57% of the students still used sequential reasoning to explain current flow. Similar to McDermott (1984), Mestre et al. (1987), and Resnick (1983), Picciarelli et al. (1991) concluded that traditional instruction was not very effective in altering common misconceptions. The researchers suggested that more dynamic instructional approaches based on pedagogical models that take into account students' misconceptions should be integrated into normal classroom activities.

### **Constructivism and Conceptual Change**

Constructivists contend that learners use their perceptions, thoughts, experiences, and memory to build mental representations of the world. These

mental representations (or schemata) are used to interpret new situations ( Von Glasersfeld, 1989). Based on Piaget's assimilation, accommodation, and disequilibrium constructs as cited in Posner, Strike, Hewson, & Gertzog (1982), conceptual change theory seeks to explain how a person's existing conceptions function in judging new conceptions by describing the conditions necessary for a major conceptual change (Strike & Posner, 1985). Using the term accommodation to refer to large-scale, holistic conceptual changes and assimilation to refer to the kinds of learning where major conceptual revision is not required, Posner et al. (1982) suggested that four conditions must exist for an individual to acquire a new conception (accommodate).

1. The student must become dissatisfied with his/her current conception; he/she must perceive and experience the limitations of his/her current conception to solve the problem.
2. The new conception must be intelligible to the student; the student must be able to understand how the procedures of the new conception solve the current problem.
3. The new conception must be plausible; the new conception must be believable by the student as an efficient method to solve the problem.
4. The new conception must be fruitful; the new conception must be practical in solving the problem in order for the student to adopt it.

Because a student's science conceptions are developed through personal experiences over time, students' conceptions about science phenomena tend to be very persistent. However, if their existing conceptions appear to be ineffective in solving a problem, dissatisfaction for the concept may develop within the student. When students are intellectually dissatisfied with their existing

conceptions, the likelihood of them accepting alternative conceptions increases (Posner et al. 1982). Constructivist views of knowledge suggest that if instructional experiences illustrate how a new conception is more intelligible, plausible, and fruitful than the existing conception, student acceptance of the new conception may occur (Nussbaum & Novick, 1981; Strike & Posner, 1985).

Much of existing research on science misconceptions and learning is focused on the development of instructional strategies to implement a conceptual change approach to learning. Techniques that enable students to activate their existing conceptions of science phenomena, compare and contrast those conceptions with alternative explanations, and internalize and maintain more accurate conceptions, have great promise for altering students' science misconceptions. Instructional strategies that facilitate conceptual change currently under investigation as well as the potential of new strategies are discussed in subsequent sections.

### **Strategies to Facilitate Conceptual Change**

#### **Text modification**

To examine the effectiveness of a conceptual change model of learning, many researchers have modified the narrative of books and lessons. That is, traditional text explanations of science concepts have been redesigned to incorporate the four conditions of the conceptual change model in order to develop instruction that directs students to experience these conditions and change their conceptions (Driver, 1989).

Conceptual change-based modifications to traditional text have tended to center on students' existing conceptions about a science phenomena (Hewson



and Thorley, 1989). The purpose of this approach was to raise the status of the scientific conception in the mind of the student and lower the status of the student's misconception. Investigating middle school students' misconceptions about photosynthesis, Roth's (1985a) use of conceptual change-based text was significantly more effective than traditional text in assisting students in altering their misconceptions. Similar to Roth, Carlsen (1989) and Wang (1991) modified traditional text by incorporating a conceptual change approach to overcome students' misconceptions about electricity. Results from both Wang's (1991) and Carlsen's (1989) studies suggested that conceptual change designed text was significantly more effective than traditional text in altering students' conceptions about science phenomena. Because conceptual change-based modifications to the narratives of science textbooks and lessons have been effective in changing students' conceptions, the integration of this approach with computer-based instruction may have potential for improving student learning about electricity.

### Computer simulations

Computer simulations enable users to manipulate variables and observe their effects in an environment that may not be possible, practical, or feasible any other way (Dekkers and Donatti, 1981; Rivers and Vockell, 1987). In the area of electricity, computer simulations have been used to allow students to build and trouble shoot circuits (White and Frederiksen, 1987; Carlsen, 1989). White and Frederiksen (1987) provided students with causal qualitative explanations of circuit operations via computer simulations. The results suggested that simulations effectively enabled students to experience the qualitative aspects of circuits and to learn to properly apply formulas for resistance and voltage.

Computer simulations that incorporate a conceptual change approach to instruction have been investigated (Zietsman and Hewson, 1986; Carlsen, 1989). Carlsen (1989) found that conceptual change designed text supplemented by a computer simulation on electrical circuits was effective in altering misconceptions. The results of studies that incorporated conceptual change and computer simulations suggested that this combination of techniques was effective in overcoming science misconceptions (Zietsman and Hewson, 1986; Carlsen, 1989). The conditions of conceptual change were integrated into the computer simulation activities of the study reported in this paper to examine their effects on student learning about electrical circuits.

### Reflection and Journals

Many who support the constructivist view of knowledge purport that the purpose of active learning is to engage students in cognitive processes and facilitate the construction of knowledge. Reflection is one technique that can heighten student's awareness of their cognitive processes. Used often in the professional preparation of teachers and education administrators, reflection has been defined as "making knowledge which is normally tacit more explicit" (Hewson, Hewson, and Jensen, 1989; p.4). Because the process of reflection caused students to become acutely cognizant of their experiences, Dewey (1933) argued that students did not actually learn from experience alone as much as they learned from reflecting on experience.

Writing can be a powerful means to facilitate reflection because it enables students to document their conceptions of various experiences (Posner, 1985). Because writing allows an individual to physically record and review their

conceptions, Kottkamp (1990) suggested that writing encouraged the construction of knowledge by helping students see relationships between various concepts.

Because they are adaptable in form and purpose, writing journals as a means of reflection have been used in a variety of educational environments (Fuller, 1987; Schmuck, 1988; Barnett & Brill, 1989). Malachowski (1988) used student journals in a chemistry course to investigate their effect on student understanding. Malachowski reported that having students describe in their own words what they observed and to comment on the significance of their observations was an efficient way to use journals and a technique that appeared to increase student understanding. The use of student journals as a means of encouraging reflection and facilitating conceptual change has potential for assisting students to focus on their conceptions and construct their own knowledge. The effect of journals on student learning of science concepts needs further examination. In the study reported in this paper, the effect of student journals and computer simulations on learning about electrical circuits was investigated.

### Ideational Confrontation

Initially used to alter physics misconceptions, ideational confrontation is a conceptual change instructional strategy (Champagne, Gunstone, and Klopfer, 1985a). A discussion-based technique, ideational confrontation is initiated when students are asked to make a prediction about a phenomena and then explain and justify their predictions. Following the articulation of their justifications, the phenomena is demonstrated; differences between what was observed in the demonstration and what students' predicted are noted.

Students are encouraged to question and challenge the results of the demonstration if the results differed with their original predictions. When students challenge results, additional demonstrations of the phenomena are conducted to address students' questions. Finally, students are led to the realization that their conceptions are inaccurate. The correct scientific explanation of the physical situation is then provided followed by discussions in which students are encouraged to express differences between their conceptions and the scientifically accurate one. The goal of this final discussion, and the entire strategy, is to encourage students to realize the inaccuracies of their conceptions and accept the scientifically correct conception.

The use of ideational confrontation as a strategy to facilitate conceptual change has been effective with middle school physics students (Champagne et al., 1985a); so much so, that its potential with diverse groups and other science concepts warrants further investigation. The techniques of ideational confrontation were used in conjunction with student journals and computer simulations to examine the potential of these strategies to facilitate conceptual change about electricity concepts.

Researchers have operationalized the conceptual change model (as articulated by Posner et al. 1982) by modifying the narratives of textbooks and lessons (Driver, 1989). Some researchers have combined computer simulations and conceptual change designed instruction to significantly improve student learning (Zietsman and Hewson, 1986; Carlsen, 1989). Because reflection through writing encourages students to become more cognizant of their conceptions, its potential in facilitating the acceptance of scientifically correct concepts should be investigated with conceptual change-based computer simulations to further

examine the effect of these strategies. Moreover, because discussion-based strategies to facilitate conceptual change, such as ideational confrontation, have been effective with middle school students, the potential effects on student learning of combining these techniques with computer simulations and journals also warrants investigation.

Currently, no research exists which investigates the combination of these techniques and their possible interactions to facilitate conceptual change about electrical circuits. The purpose of this study was to investigate the effectiveness of a conceptual change approach using computer simulations and the effectiveness of reflective journals with peer group interactions for overcoming preservice teachers' misconceptions about current flow within electrical circuits.

### Hypothesis

In this study, four instructional treatments were used to examine the effects of conceptual change computer simulations, reflective writing, and peer group interactions on student learning about electrical circuits. The treatments were: (a) computer-based didactic lesson (control group); (b) conceptual change computer simulation; (c) conceptual change computer simulation and reflective writing activities; and (d) conceptual change computer simulation, reflective writing activities and peer group interactions.

It was hypothesized that the variations in the four treatments would have an additive effect on preservice teacher achievement scores on tests measuring their understanding of basic electricity concepts. That is, the conceptual change computer simulation (CCCS) treatment would have a greater effect than computer-based didactic instruction (CP) treatment; the conceptual change

computer simulation and reflective writing (CCCSW) treatment would have a greater effect than the CCCS treatment; and the conceptual change computer simulation, reflective writing, and peer group interaction (CCCSWPIG) treatment would have a greater effect than the CCCSW treatment on preservice teacher achievement as determined by scores on the Electrical Circuits Posttest.

## METHODOLOGY

### Subjects

The participants were 155 undergraduate students (121 females 34 males) who had been accepted into the teacher education program (minimum grade point average of 2.5 required) and who were enrolled in a required media course for preservice teachers. Nine of the 10 sections of the Instructional Media course participated in the study. Of 155 students in these sections, 116 (92 females and 24 males) completed all three components of the study. The remaining subjects (N=39) did not complete all aspects of the study because of absence, or they did not complete the study activities in the manner intended. Six of the 116 students did not complete each item of the Electricity Interest and Experience Inventory (EI)<sup>2</sup>; these individuals were listed as missing cases in some of the analyses reported below.

The participants were elementary education majors (60%), secondary education majors (20%), science majors (4%), and others (other discipline majors and those who did not provide information concerning their major) (16%); 77% were seniors, 16% were juniors, 52% were between the ages of 19 and 21, 33% were ages 22-24, and 15% were 25 or over. A summary of the complete demographic data is available in Appendix A - Table 2. For the 82 participants for whom ACT scores were available, the students' average composite ACT score was 21 with a standard deviation of 4.

### Design

In each section of the course, the students were randomly assigned to one of four treatment groups. The four treatment groups were:

1. Computer-based didactic lesson control group (CP). Students who participated in the CP treatment completed a computer-based instructional lesson about simple electrical circuits that used a traditional instructional design.
2. Conceptual change computer simulation (CCCS). Students who participated in the CCCS treatment completed a computer-based instructional lesson about simple electrical circuits that used a conceptual change approach.
3. Conceptual change computer simulation and reflective writing (CCCSW). Students who participated in the CCCSW treatment completed the same computer lesson as the CCCS treatment group and also recorded their perceptions about the concepts presented in the computer lesson in student journals.
4. Conceptual change computer simulation, writing and peer group interaction (CCCSWPIG). Students who participated in the CCCSWPIG treatment, completed the same activities as the CCCSW treatment group and also participated in group discussions about the electricity concepts presented in the computer program.

## **Materials**

### Instructional computer program

Students completed either a didactic Hypercard lesson (control group treatment) or a Hypercard lesson employing simulations (experimental group treatments) that taught the same basic concepts about electrical circuits. The topics included were: (a) definition of electrical energy (explanation of protons and electrons, electrochemical cells, and components of a circuit), (b) nature of electrical circuits, (c) measuring electrical parameters, (d) series circuits, (e)



distribution of electrical energy within a series circuit, and (f) dead batteries. In the didactic and simulation lessons, the screen appeared as in Figure 1. Both lessons were contained in one Hypercard Stack that had 216 cards, and incorporated text, graphics, and animation. A printed copy of the cards that comprised the lessons, and a computer disk containing the Hypercard stack appear in Appendix I.

The content of the computer program was revised from one used by Carlsen (1989). Carlsen's traditional text material and conceptual change text material were developed from two junior and senior high school science textbooks (Murphy, Hollon, & Zitzewitz, 1986; Ramsey, Gabriel, Mc Guirk, Phillips, & Watenpaugh, 1986). Four high school and college physics textbooks (Cutnell and Johnson, 1992; Hewitt, 1985; Taffel, 1981; Abbott, 1976) that were recommended by a university physics professor and a high school physics teacher served as the primary information sources used to revise Carlsen's lesson. Two physicists from Ames Laboratory of the U.S. Department of Energy and Iowa State University and one high school physics teacher reviewed the content of the computer lesson to verify its accuracy.

The results of two pilot tests indicated that the simulation lesson required approximately 15% to 25% more time to complete than the didactic lesson. To ensure that approximately the same amount of time was needed to complete each lesson, instruction on how a wire must be connected to a bulb to complete a circuit, information about short circuits, and additional calculation problems were added to the didactic lesson to lengthen the amount of time required for completion. The simulation lesson did not include this additional material.

### Didactic lesson

The didactic lesson, which served as the control treatment, was used only by students in the CP treatment and was similar to a textbook in that it presented content in sequence. Like a typical textbook, the information was presented to the students with little consideration given for their existing preconceptions about electricity. During the didactic lesson, "pop-up" statements appeared on the screen. The "pop-up" statements requested students to perform various calculations using Ohm's law.

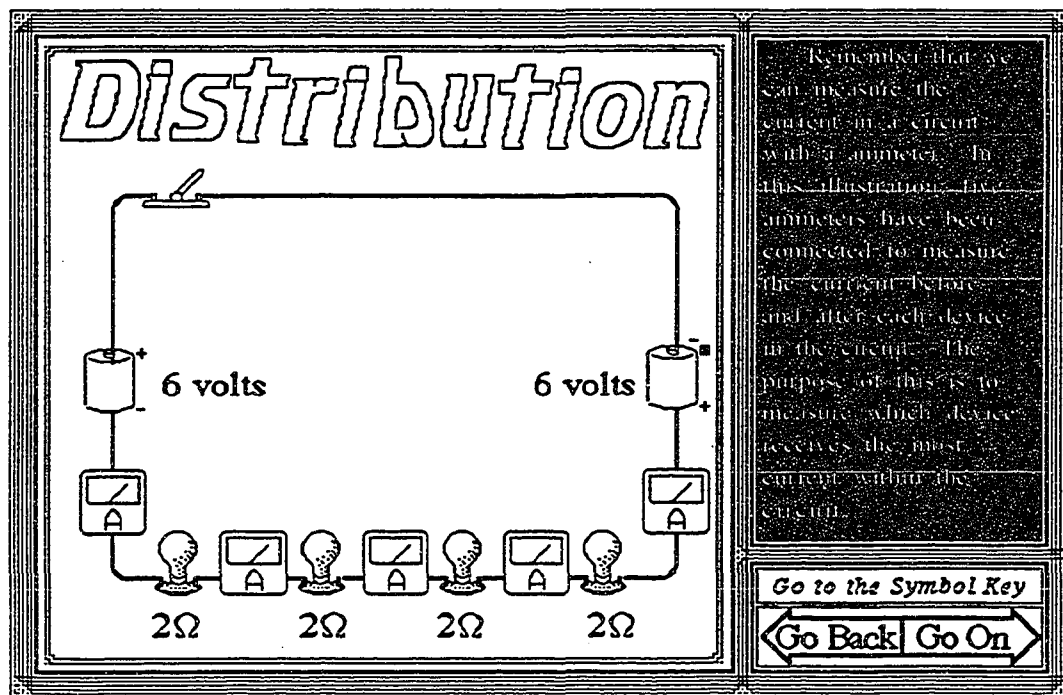


Figure 1 Typical card in both the didactic and simulation lessons.

Student interaction with the computer during the didactic lesson was limited to using the mouse to move forward or backward to each screen of the lesson. The directions used for the CP treatment appear in Appendix E.

### Simulation lesson

The simulation lesson, used by students in the CCCS, CCCSW, and CCCSWPIG treatments, applied the Posner et al. (1982) conceptual change approach to instruction. The lesson encouraged students to become more cognizant of their existing conceptions about specific electricity concepts by asking them to explain how various features of electrical circuits operated (e.g. describe how a circuit must be constructed to cause a bulb to light). The students used the computer to build a simulated circuit and test their conceptions, to receive instruction on why their conceptions were or were not scientifically correct, and then to receive instruction on the scientific explanation of the concept.

Similar to the didactic lesson, "pop-up" statements appeared on the screen throughout the simulation lesson. The statements in the simulation lesson requested the students to perform various calculations using Ohm's law or to describe how they thought various components of electrical circuits operated (e.g. explain how current flows in a circuit to cause a bulb to light). According to the treatment, the students were instructed how to respond to the statements. Students in the CCCS treatment were given scratch paper and directed to perform the calculations; however, they did not write their answers to the "pop-up" statements on how components of electrical circuits operated, but thought about their answers to these statements.

Students in the CCCSW and CCCSWPIG were given journals in which they responded in writing to each "pop-up" statement that appeared on the screen. The directions used for the CCCS, CCCSW, and CCCSWPIG treatments appear in Appendix E.

#### Student reflective journals

Each student participating in the CCCSW and the CCCSWPIG treatments completed a student journal. The journals were used to generate written responses to the "pop-up" statements that appeared throughout the computer program. The journals included the "pop-up" statements that appeared on the computer screen and space for the student to respond to the statements. In addition to the "pop-up" statements, the CCCSWPIG journal included two additional questions for each electricity concept; these two questions were not included in the CCCSW journal. The student journals appear in Appendix F.

#### Ideational confrontation technique

A critical component of the CCCSWPIG treatment was the discussion activity. Based on the ideational confrontation strategy (Champagne, Gunstone, and Klopfer, 1985a), the discussion component occurred only in the CCCSWPIG treatment and occurred at the beginning and ending of each electricity concept examined in the lesson.

Under the guidance of a facilitator, students who participated in the CCCSWPIG treatment viewed, as a group, selected portions of the simulation lesson that were projected from the facilitator's computer on to a screen. At the

conclusion of each section, a "pop-up" statement appeared on the screen that asked the students to state their beliefs concerning a particular electricity principle (e.g. is it possible to construct a series circuit with four devices in which three of the devices are on and one is off?). The students were directed to record their beliefs in their journals. They then were led in a discussion where they were asked to share their beliefs and justify their views concerning a particular electricity principle.

After the first discussion, each student worked individually at a computer using the simulation to test their beliefs. When all students were finished, a second discussion was conducted in which the students reported what they had experienced with the computer program. They were asked to compare their initial beliefs with what had occurred in the computer program. Following the discussion, the students were directed to record in their journals what had occurred during the computer program and the differences (if any) in their initial beliefs and their present beliefs. A printed copy of the cards comprising the five sections of the simulation lesson that were viewed collectively and the CCCSWPIG facilitator guidelines are included in Appendix E.

#### Electricity interest and experience inventory

Adapted from a test used by Chambers and Andre (1991), the 32 item Electricity Interest and Experience Inventory [(EI)<sup>2</sup>] was designed to collect demographic data and data about the students' interest in and experience with electricity. Thirteen items requested information on the students' major, academic classification, gender, age, and computer experience. Twelve items addressed student interest in electricity. Seven items addressed students'

experiences with electricity. The participants' responses to the (EI)<sup>2</sup> were used to determine electricity interest and experience differences among the participants. The (EI)<sup>2</sup> appears in Appendix D.

### Electricity posttest

The 29 multiple-choice item posttest, adapted from Carlsen (1989) and Chambers and Andre (1991), measured students' understanding of basic electrical circuits. Twenty five of the items were diagrams of possible circuits that assessed students' qualitative understanding of current flow within electrical circuits (here on referred to as the conceptual understanding section). Students were asked if the circuits would or would not work. Many of the incorrect explanations were based on common electricity misconceptions. Figure 2 contains an example of an item included on the posttest.

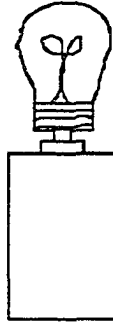
Four additional calculation items tested students' ability to recall and apply Ohm's law and calculate voltage, resistance, and amperage. One item was discarded. Two forms of the posttest, containing the same items in rearranged orders, were administered (Appendix D).

### Room facilities and computers

Experimental sessions were held in university classrooms. Each classroom was equipped with five Macintosh computers (one for each student). In addition to the computers, the tables and chairs in the rooms were arranged to enable students to work individually at the computer and as a group during discussions.

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Will the bulb light in the diagram below?



- a. Yes, because electricity can flow from the bump on the top of the battery to the light bulb directly.
- b. Yes, because any connection between the battery and the light bulb will cause the bulb to light.
- c. No, because the wire is connected to the wrong part of the light bulb.
- d. No, because electricity cannot flow in the circuit.
- e. No, because electricity can only flow out of the other side of the battery, not the side the wire is connected to.

Figure 2. Example of the items included on Electrical Circuits Posttest

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### Facilitator preparations

Nine individuals, who had previously taught or were currently teaching the Instructional Media course, volunteered to facilitate the treatment sessions for the study. Two training sessions were held to familiarize the facilitators with the Hypercard stack about electricity and the procedures to be used for the treatments. A detailed explanation of the training sessions and the training materials are included in Appendix H.

To maintain the consistency of the CCCSWPIG treatment, the same individual facilitated all of the CCCSWPIG treatment sessions. Two training

sessions were conducted for this facilitator; the training sessions focused on the ideational confrontation technique to be used during the group discussions.

## Procedures

### Introduction of study to subjects

One to two weeks prior to the treatment, each section received a description of the purpose of the electricity computer lesson activities and their assignment. In addition, each student signed a consent letter, and completed the (EI)<sup>2</sup>. The students were told that the electricity computer lesson activities would demonstrate to them effective methods of using computers in classes. It was stressed that student performance on the computer activities would not influence their course grades, although their homework assignment did account for five percent of the total points possible in the course. This homework assignment was unrelated to the content of the lesson. The consent letter and the assignment based on the electricity computer lesson activities appear in Appendix G.

### Treatments

Prior to the experiment, the researcher randomly assigned the students to treatments. (A description of the procedures used to assign students to treatments is included in Appendix J.) During the treatment sessions, the section's instructor introduced the study's facilitators and assigned the students to treatment groups according to a list of random assignments. Each group of students went to its assigned room to participate in the computer activities.



In the treatment rooms, each student was assigned a computer. The facilitator distributed materials appropriate for the treatment, read the treatment directions aloud and directed students to begin. Directions on the operation of a mouse were provided when needed. The students were required to work with the computer activity a minimum of 45 minutes to a maximum of one hour.

After completing the electricity computer lesson, the students turned in their materials and were given the posttest. One week later, students completed the second form of the posttest during their Instructional Media class. The students had not been told that a second posttest would be given.

## RESULTS

The reliability estimates (Cronbach's alpha) for the Electrical Circuits Posttest 1 and 2 were .74 and .77 respectively. The (EI)<sup>2</sup> reliability estimate was .95. The internal consistencies of the calculation sections of each posttest were low, so analyses were calculated using the 29 item posttest and the 25 item conceptual understanding section. The internal consistencies for the Electrical Circuits Posttest and the (EI)<sup>2</sup> are presented in Appendix A - Table 1.

### Electricity Interest and Experience Inventory

The purpose of the (EI)<sup>2</sup> was to provide a covariate. The internal consistency (alpha) of the (EI)<sup>2</sup> was .95. A one way analysis of variance (ANOVA) revealed that the treatment groups did not differ significantly on (EI)<sup>2</sup> scores ( Appendix A - Table 3). (EI)<sup>2</sup> correlated .41 and .33 with the Electrical Circuits Posttest 1 and 2, respectively. Appendix A - Table 4 presents the averages and standard deviations for each treatment on (EI)<sup>2</sup>.

The researcher had originally intended to use ACT as a covariate as well. However, because the university did not require ACT for admissions, ACT scores were available for only 82 of the students. A one way ANOVA conducted on scores of students for whom ACT scores were available failed to find significant differences between the treatments. Appendix A - Table 6 presents the averages and standard deviations for each treatment group on ACT, and Appendix A - Table 9 presents the averages and standard deviations for each treatment group on the posttests.

An ANOVA was conducted on the participants' composite ACT scores to assess if the treatment groups were equivalent in terms of academic ability. The results of the ANOVA indicated that there was not a significant difference

on ACT scores between the treatment groups [ $F(3,81) = .85, p < .70$ ] (Appendix A - Table 5).

### Correlations

To examine all possible relationships that existed among and between potentially confounding independent variables and the Electrical Circuits Posttest, a series of correlations was completed (Appendix A - Table 7). All of the correlations were statistically significant at the .05 level. As expected, posttests 1 and 2 had the highest correlation ( $r = .71$ ); 50% of the variance of each posttest was associated with the other. Although statistically significant, ACT score and posttest 2 had the lowest correlation ( $r = .29$ ); Only 8% of the variance in posttest 2 was associated with ACT score. Because  $(EI)^2$  was moderately correlated with Electrical Circuits Posttest 1 and 2 ( $r = .41, p > .01$ ;  $r = .33, p < .01$ ), it was used as a covariate with the analyses of the Electrical Circuits Posttest scores. To control for the effect of  $(EI)^2$  on student performance on the posttest,  $(EI)^2$  was used to control for any differences between students.

### Electrical Circuits Posttest 1

A one way analysis of covariance (ANCOVA) was completed using the posttest 1 total scores. There was no significant difference between average scores of the four treatment groups on Electrical Circuits Posttest 1 [ $F(3,105) = .98, p = .41$ ] (Appendix A - Table 8).

A separate one way ANCOVA was completed for only the conceptual understanding section of the posttest (Appendix A - Table 10). There was no significant difference due between treatments [ $F(10,67) = .57, p = .64$ ]. The

averages and standard deviations for the conceptual understanding sections of the Electrical Circuit Posttest 1 and 2 appear in Appendix A - Table 11.

### **Electrical Circuits Posttest 2**

A one way ANCOVA for the total scores of the Electrical Circuits Posttest 2 showed that there was no significant difference between the treatment groups [ $F(3,105) = .15, p = .93$ ] (Appendix A - Table 12). A separate ANCOVA was calculated using only the conceptual understanding section scores (Appendix A - Table 13). Again, the effect of the treatment was not [ $F(1,51) = .06, p = .98$ ].

### **Factor Analysis of Electrical Circuits Posttests**

To examine the possible differential influence of the treatments on subsections of Electrical Circuits Posttest 1 and 2, a factor analysis of the Electrical Circuits Posttest was completed. As described by Wolins (1986), the factor analysis procedure used a varimax rotation technique. Five sub-tests (here on referred to as factors) emerged; they were:

1. Connection to the bulb (BULB) - items measuring a student's knowledge of where a wire must be connected to a bulb to complete a circuit;
2. Correct connection with one bulb (CBULB) - items measuring a student's knowledge of a correct circuit with a single bulb;
3. Wire connection to bulb glass (GLASS) - items measuring a student's knowledge of circuits with a wire connection to glass casing of a bulb;
4. Series circuit (SERIES) - items measuring a student's knowledge of circuits with multiple devices connected in series; and

5. Single wire connection (SINK) - items measuring a student's knowledge of circuits with only one wire connecting a battery and a bulb.

The factors from posttest 2 were titled as follows: (a) Connection to the bulb (BULB2); (b) Correct connection with one bulb (CBULB2); (c) Wire connection to bulb glass (GLASS2); (d) series circuit (SERIES2); and (e) single wire connection (SINK2). The item loadings of Electrical Circuits Posttest 1 and 2 factors are reported in Appendix B - Table 1. The internal consistency alpha for each factor is also reported.

#### **Correlations Among Electrical Circuits Posttest Factors**

For comparison purposes, factor scores for each participant were calculated and converted to proportions. For each treatment, the averages and standard deviations of the factors are reported in Appendix B - Table 2. To examine the relationships that existed among the factors, a series of correlations were completed for the factors from both Electrical Circuits Posttests. The correlations examined relations among and between the factors (Appendix B - Table 3).

#### **Analyses of Electrical Circuits Posttest 1 and 2 Factors**

Using the five factor scores from each posttest as levels of an independent variable labeled test type, two separate  $4 \times 5$  multiple ANCOVAs were completed. Treatment was the between subjects factor and test type was the within subjects factor (Appendix B - Table 4a & 4b). The results indicated that there was an interaction between the treatments and factors. There was not an interaction between test time and factors or test time and treatment. The

averages and standard deviations for these data are presented in Appendix B - Table 5.

To examine the interaction between treatments and factors, a one way ANOVA with treatment as the independent variable was conducted using each factor score from Electrical Circuits Posttest 1 and 2 (Appendix B - Table 5). The results of the Student Newman-Kuels post-hoc analysis (Hinkle, Wiersma, & Jurs, 1988) indicated that there was a significant difference between the experimental treatment groups and the control group on the Electrical Circuits Posttest 1 BULB factor [ $F(3,115) = 5.34$   $p < .01$ ]. That is, on items concerning how wires must be connected to bulbs, the CP treatment group scored significantly higher than the three experimental treatment groups. On posttest 2, the CP treatment group scored significantly higher than the CCCSWPIG treatment group on the BULB factor [ $F(3,115) = 2.90$   $p = .04$ ]. The data from each post-hoc ANOVA completed on each factor are presented in Appendix C - Table 1.

The Student Newman-Kuels ANOVA completed using the Electrical Circuits Posttest factors by treatment groups revealed that there was a significant difference between the three experimental treatment groups and the CP (control) treatment group on the Electrical Circuits Posttest SINK factors. On posttest 1, the experimental treatment groups scored significantly higher than the control group on items that had a single wire connection [ $F(3,115) = 4.34$   $p < .01$ ]. Also, on posttest 2 the experimental treatment groups scored significantly higher than the control group in the SINK factor [ $F(3,115) = 6.22$   $p < .01$ ] (Appendix C - Table 1). Moreover, the data indicated that, although not statistically significant, the treatment effects were additive; that

is, the CCCS treatment had a greater effect than the CP treatment; the CCCSW treatment had a greater effect than the CCCS treatment; and the CCCSWPIG treatment had a greater effect than the CCCSW treatment on items that related to the understanding of a single wire connection.

## DISCUSSION

In the study, students were assigned to one of four treatment groups (Computer-based didactic lesson, Conceptual change computer simulation, Conceptual change computer simulation and reflective writing, and Conceptual change computer simulation, writing and peer interaction). All of the students completed a computer-based instruction lesson about simple electrical circuits. Students were required to participate in treatment activities between a minimum of 45 minutes to a maximum of one hour. The amount of time for the treatments was a limitation to the study. Because the variations in experimental treatments involved the addition of activities (i.e., writing, and writing and peer interactions), the need for more time in the more complex treatments was inherent in the treatment differences. The limited amount of time may not have allowed for the instructional potential of the treatments to be realized.

To ensure that each implementation of the conceptual change computer simulation, writing and peer interaction treatment was consistent, the same individual facilitated each session. The facilitator variable may have affected the conceptual change computer simulation, writing and peer interaction treatment.

Participants in the study were 116 preservice teachers enrolled in a required teacher education course. Because the treatments involved instructional uses of computers, the activities of the study were incorporated into an Instructional Media course; the context in which the study was implemented may have limited its effect. Overall, student performance on the Electrical Circuits Posttests was lower than expected; their poor



performance may be due in part to a lack of interest and a lack of accountability. Because the students had little interest in the topic of electricity, as indicated by the (EI)<sup>2</sup>, and because they were not accountable for the content of the computer-based instruction lesson as part of the course, the overall effectiveness of the treatments may have been limited.

The Electrical Circuits Posttest assessed students' understanding of the flow of current in simple electrical circuits. The internal consistency estimates of Electrical Circuits Posttest 1 (.74) and Posttest 2 (.77), indicated that the tests were reliable. Overall, there was not a significant difference in the average scores for students in each of the treatment groups; nor did the treatments have an additive effect on student achievement as measured by the Electrical Circuits Posttest.

The Electrical Circuit Posttest consisted of 25 conceptual understanding items and four calculation items. The analysis of the participants' scores for the conceptual understanding items of both posttests indicated that there was not a significant difference between treatment groups. However, the average scores for the experimental treatment groups increased on the second posttest, and the average of the control group decreased. Although the increases of the experimental treatment groups on the second posttest were not significantly greater than the scores on the first posttest, the results suggested that the experimental treatments may have facilitated long-term retention of scientifically correct concepts. Future studies should extend the length of the treatments to further examine the differential effectiveness of the experimental treatments in order to assist students in altering their

conceptions about electricity and maintaining scientifically correct conceptions over time.

A factor analysis indicated that there were five factors within the Electrical Circuits Posttest. Analysis of the factors revealed that the control group performed significantly better than the experimental groups on items concerning how a wire is connected to a bulb to complete a circuit. Given that the control group received explicit instruction on this concept and the experimental treatments did not receive any instruction on this concept, these differences were not surprising.

The experimental treatments were effective in assisting students in overcoming misconceptions concerning single wire connections. Analysis of the SINK factor of the Electrical Circuits Posttest indicated that the experimental treatment groups performed significantly better than the control group on both posttests. As part of the experimental treatments, the explicit confrontation of students' misconceptions about single wire circuit connections was apparently effective in altering students conceptions about circuits. Moreover, although not statistically significant for the SINK factor, the treatments showed an additive effect on student achievement. That is, the CCCS treatment group performed better than the CP treatment group, the CCCSW treatment group performed better than the CCCS treatment group, and the CCCSWPIG treatment group performed better than the CCCSW treatment group. These results suggest that the combined use of reflective journals, peer interactions, and conceptual change differentially effected student achievement in learning science concepts. Future studies should

investigate their potential within the context of a science teaching methodology course.

### Summary

The results of this study indicated that the variations of the conceptual change computer simulation treatments did not have an additive effect on the Electrical Circuits Posttest scores of students preparing to be K-12 teachers. Moreover, there was no significant difference between the conceptual change computer simulation treatment groups and the control group on the Electrical Circuits Posttest scores.

The analysis indicated that the overall average on the conceptual understanding section of the second Electrical Circuits Posttest was higher than the overall average for the same section on Posttest 1. Although the improved performance was not statistically significant, each of the experimental treatment groups performed better on the conceptual understanding section of the second posttest than they had on the first posttest. The control group did not perform as well on the conceptual understanding section of the second posttest as they had on that section of the first posttest.

Analyses of the factors within the posttest, revealed that the experimental treatments were effective in helping students overcome misconceptions about single wire connections. This suggested that explicitly confronting misconceptions through the combined use of computer simulations, reflective journals, and peer group interactions may encourage and assist students in altering their misconceptions and accepting scientifically correct conceptions of electricity over time.

Future studies should extend the instructional period of the treatment to better assess the effectiveness of the treatment variations to change students' conceptions about electrical circuits. Unlike Carlsen (1989), whose treatment was implemented over three days, the instructional treatment lasted approximately one hour. In addition, the treatments should be incorporated into a more natural classroom situation for preservice teachers such as a science teaching methodology course.

## CONCLUSION

Altering students' conceptions of science concepts is a formidable task. Research suggests that explicitly confronting students' misconceptions about science principles is necessary in order to alter students' conceptions. This study investigated the use of a conceptual change approach with computer simulations to alter preservice teachers' conceptions of electricity. In addition, reflective journals and ideational confrontation techniques were employed with the computer-based conceptual change approach to alter students' misconceptions about electrical circuits.

The results of this study indicated that there was no significant difference in the conceptual change computer-based instructional treatments and the traditional computer-based instructional treatment in student performance on Electrical Circuits Posttest. However, student performance on the second posttest improved for those in the experimental treatments. Analysis of the factors of the Electrical Circuits Posttest revealed that the conceptual change-based treatments were significantly more effective than the control treatment in altering students' misconceptions about single wire connections. Future research should extend the treatment time to fully actualize the differential effects of the experimental treatments. Such studies should be conducted within the context of a science teaching methodology course for preservice teachers.

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## APPENDIX A. TABLES

Table 1 Reliabilities: Electrical Circuits Posttest 1 and 2 and (EI)<sup>2</sup> using Cronbach's alpha (Hinkle, Wiersma, Jurs, 1988).

Test	Reliability
Posttest 1	.74
Conceptual Understanding section	.74
Calculation section	.20
Posttest 2	.77
Conceptual Understanding section	.78
Calculation section	.22
(EI) <sup>2</sup>	.95

Legend:

- Posttest 1 - first administration of Electrical Circuits Posttest
- Posttest 2 - second administration of Electrical Circuits Posttest
- (EI)<sup>2</sup> - Electricity Interest and Experience Inventory

Table 2 Frequency distributions: Demographic data

ITEMS	N	PERCENT
<b>GENDER</b>		
Male	24	20.7
Female	<u>92</u>	<u>79.3</u>
	116	100.0
<b>ACADEMIC CLASS</b>		
Junior	18	15.5
Senior	89	76.7
Other	<u>9</u>	<u>7.8</u>
	116	100.0
<b>MAJOR</b>		
Education	93	80.2
Science	5	4.3
Other or Not Specified	<u>18</u>	<u>15.5</u>
	116	100.0
<b>AGE</b>		
19-21	60	51.7
22-25	38	32.6
25 or more	<u>18</u>	<u>15.5</u>
	116	100.0
<b>COMPUTER MOST USED</b>		
Macintosh	46	49.7
Apple	27	23.5
MS DOS/IBM	37	32.2
Other	2	1.7
Never Used	<u>3</u>	<u>2.6</u>
	116	100.0
<b>USE OF MOUSE</b>		
YES	100	87.0
NO	<u>15</u>	<u>13.0</u>
	115	100.0
<hr/>		
<b>*COMFORT WITH COMPUTERS</b>		
Very Comfortable	38	32.8
Comfortable	35	30.2
Some Comfort	34	29.3
Very Uncomfortable	<u>9</u>	<u>7.8</u>
	116	100.0

MEAN = 2.12

SD = .92

\*Comfort with computers refers to participants' rating of personal level of comfort in using a mouse and computer.

Table 3 Analysis of variance: (EI)<sup>2</sup> by treatments.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F	SIG. OF F
Treatment	22.41	3	7.47	.83	.48
Residual	950.66	106	8.97		

6 cases (5.2%) were missing

Table 4 Means and standard deviations: (EI)<sup>2</sup> for each treatment.

Treatment	CP	CCCS	CCCSW	CCCSWPIG	OVERALL MEAN
N	28	29	26	27	110
X	3.43	3.45	3.46	4.45	3.67
SD	2.15	2.79	2.63	4.09	2.99
Range	2-14	2-14	3-14	3-15	2-15
Possible Range	0-17	0-17	0-17	0-17	0-17

Legend:

(EI)<sup>2</sup> - Electricity Interest and Experience Inventory

(EI)<sup>2</sup> scale

0 =Little or no interest in and experience with electricity

17 =Extremely interested in and experienced with electricity

## Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 5 Analysis of variance: Composite ACT scores by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F	SIG. OF F
Treatment	27.74	3	9.25	.85	.70
Residual	1496.95	78	19.19		

34 cases (29%) were missing

Table 6 Means and standard deviations: Composite ACT scores for each treatment.

Treatment	CP	CCCS	CCCSW	CCCSWPIG	OVERALL MEAN
N	21	24	17	20	82*
X	20.29	21.00	20.59	21.85	20.94
SD	4.33	5.07	4.36	3.45	4.34
Range	15-29	14-35	14-31	17-30	14-35
Possible Range	0-36	0-36	0-36	0-36	0-36

\*ACT scores not available for 34 (29%) participants

Legend:

ACT

Higher score indicated higher achievement

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 7 Pearson Product Moment Correlation coefficients: Electrical Circuits Posttest, ACT, and (EI)<sup>2</sup>.

	Posttest 1	Posttest 2	(EI) <sup>2</sup>	ACT
Posttest 1				
Posttest 2	.71**			
(EI) <sup>2</sup>	.41**	.33**		
ACT	.43**	.29**	.46**	

\*\* .01 level

Legend:

Posttest 1 - first administration of Electrical Circuits Posttest

Posttest 2 - second administration of Electrical Circuits Posttest

(EI)<sup>2</sup> - Electricity Interest and Experience Inventory

ACT - measure of academic ability; composite score on American College Tests

Table 8 Analysis of covariance: Electrical Circuits Posttest 1\*\* by treatments with (EI)<sup>2</sup> as a covariate.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F	SIG. OF F
Covariate	426.49	1	426.49	21.29	<.01*
Treatment	58.93	3	19.64	.98	.41
Residual	2103.76	105	20.04		

6 cases (5.2%) were missing

\*\*Means and standard deviations are presented in Table 9.



Table 9 Means and standard deviations: Electrical Circuits Posttest 1 and 2 for each treatment.

Treatment	CP		CCCS		CCCSW		CCCSWPIG		OVERALL MEAN	
Posttest	1	2	1	2	1	2	1	2	1	2
N	29	29	31	31	28	28	28	28	116	116
X	18.52	17.24	16.45	16.16	17.25	16.71	17.00	17.75	17.29	16.95
SD	5.19	5.57	4.43	4.88	5.58	6.25	4.30	4.58	4.89	5.31
Range	7-28	6-27	8-24	8-24	7-27	5-28	8-25	7-26	7-28	5-23
Possible Range	0-29	0-29	0-29	0-29	0-29	0-29	0-29	0-29	0-29	0-29

Legend:

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 10 Analysis of covariance: Electrical Circuits Posttest 1 conceptual understanding section by treatments\* with (EI)<sup>2</sup> as a covariate.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F	SIG. OF F
Covariate	334.52	1	334.52	17.89	<.01
Treatment	32.01	3	10.67	.57	.67
Residual	1963.87	105	18.70		

6 cases (5.2%) were missing

\*Means and standard deviations are presented in Table 11

Table 11 Means and standard deviations: Electrical Circuits Posttest 1 and 2 conceptual understanding section for each treatment.

Treatment	CP		CCCS		CCCSW		CCCSWPIG		OVERALL MEAN	
Posttest	1	2	1	2	1	2	1	2	1	2
N	29	29	31	31	28	28	28	28	116	116
X	16.14	16.00	14.65	15.13	15.25	15.61	15.11	16.29	15.28	15.74
SD	5.31	5.33	4.14	4.72	5.06	5.96	4.07	4.25	4.64	5.05
Range	5-22	4-24	8-24	6-24	5-22	3-24	5-22	8-24	5-24	3-24
Possible Range	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25	0-25

Legend:

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 12 Analysis of covariance: Electrical Circuits Posttest 2 by treatments\*\*  
with (EI)<sup>2</sup> as a covariate.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F	SIG. OF F
Covariate	354.01	1	354.01	13.20	<.01*
Treatment	12.10	3	4.03	.15	.93
Residual	2815.90	105	26.82		

6 cases (5.2%) were missing

\*\*Means and standard deviations are presented in Table 9

Table 13 Analysis of covariance: Electrical Circuits Posttest 2 conceptual understanding section by treatments\*\* with (EI)<sup>2</sup> as a covariate.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F	SIG. OF F
Covariate	232.18	1	232.18	9.27	<.01*
Treatment	4.54	3	1.51	.06	.98
Residual	2630.04	105	25.05		

6 cases (5.2%) were missing

\*\*Means and standard deviations are presented in Table 11.

## APPENDIX B. FACTOR TABLES

Table 1 Factor loadings and internal consistencies: Electrical Circuit Posttest 1 and 2 items.

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**FACTORS: BULB & BULB 2 - CONNECTION TO THE BULB**

<u>ITEM</u>	<u>POSTTEST 1</u>	<u>POSTTEST 2</u>
10	.73	.69
11	.74	.75
13	.74	.74
16	.73	.84
18	.76	.74
22	.53	.68
Cronbach's alpha	.86	.88

**FACTORS: CBULB & CBULB 2 - CORRECT CONNECTION WITH 1 BULB**

<u>ITEM</u>	<u>POSTTEST 1</u>	<u>POSTTEST 2</u>
7	.57	.68
9	.74	.78
14	.74	.81
15	.78	.65
19	.74	.77
20	.74	.68
Cronbach's alpha	.87	.88

**FACTORS: GLASS & GLASS 2 - WIRE CONNECTION TO GLASS BULB**

<u>ITEM</u>	<u>POSTTEST 1</u>	<u>POSTTEST 2</u>
6	.56	.57
12	.72	.72
17	.64	.72
Cronbach's alpha	.70	.71

Legend:

Factors

Names for Electrical Circuits Posttest 1 factors -BULB, CBULB, GLASS, SERIES, SINK

Names for Electrical Circuits Posttest 2 factors - BULB 2, CBULB 2, GLASS 2, S SERIES 2, S SINK 2

Table 1 cont. Factor loadings and internal consistencies: Electrical Circuit  
Posttest 1 and 2 items.

FACTORS:      SERIES & SERIES 2 - SERIES CIRCUIT			
	<u>ITEM</u>	<u>POSTTEST 1</u>	<u>POSTTEST 2</u>
	21	.89	.68
	25	.71	.83
	Cronbach's alpha	.80	.81
FACTORS:      SINK & SINK 2 - SINGLE WIRE CONNECTION			
	<u>ITEM</u>	<u>POSTTEST 1</u>	<u>POSTTEST 2</u>
	1	.74	.63
	2	.74	.81
	3	.38	.60
	4	.58	.58
	5	.65	.84
	Cronbach's alpha	.75	.82

Electrical Circuits Posttest items 8, 23, 24 did not load on the factor analysis.

Legend:

Factors

Names for Electrical Circuits Posttest 1 factors -BULB, CBULB, GLASS,  
SERIES, SINK

Names for Electrical Circuits Posttest 2 factors - BULB 2, CBULB 2,  
GLASS 2, S SERIES 2, S SINK 2



Table 2 Proportion correct: Electrical Circuits Posttest 1 and 2 factors for each treatment.

FACTOR:	BULB - Connection to the bulb			Posttest 1 items: 10, 11, 13, 16, 18, 22	OVERALL MEAN
	CP	CCCS	CCCSW	CCCSWPIG	
N	29	31	28	28	116
X	.66	.40	.39	.30	.41
SD	.36	.37	.37	.31	.37
Range	.16-1.00	.16-1.00	.16-1.00	.00-.66	.00-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

FACTOR:	BULB 2 - Connection to the bulb			Posttest 2 items: 10, 11, 13, 16, 18, 22	OVERALL MEAN
	CP	CCCS	CCCSW	CCCSWPIG	
N	29	31	28	28	116
X	.59	.41	.33	.34	.39
SD	.38	.40	.38	.34	.39
Range	.16-1.00	.16-1.00	.16-1.00	.00-.66	.00-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

Legend:

Factor scores have been converted to proportions

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 2 cont. Proportion correct: Electrical Circuits Posttest 1 and 2 factors for each treatment.

FACTOR: CBULB - Correct Connection with 1 bulb					Posttest 1 items: 7, 9, 14, 19, 20
	CP	CCCS	CCCSW	CCCSWPIG	OVERALL MEAN
N	29	31	28	28	116
X	.45	.38	.45	.48	.44
SD	.36	.35	.38	.42	.38
Range	.20-1.00	.00-1.00	.20-1.00	.20-1.00	.20-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

FACTOR: CBULB 2- Correct Connection with 1 bulb					Posttest 2 items: 7, 9, 14, 19, 20
	CP	CCCS	CCCSW	CCCSWPIG	OVERALL MEAN
N	29	31	28	28	116
X	.51	.39	.46	.45	.45
SD	.39	.35	.39	.41	.38
Range	.20-1.00	.00-1.00	.20-1.00	.20-1.00	.20-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

Legend:

Factor scores have been converted to proportions

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 2 cont. Proportion correct: Electrical Circuits Posttest 1 and 2 factors for each treatment.

FACTOR: GLASS - Wire Connection to Glass		Posttest 1 items: 6, 12, 17			
	CP	CCCS	CCCSW	CCCSWPIG	OVERALL MEAN
N	29	31	28	28	116
X	.77	.67	.71	.77	.73
SD	.34	.38	.35	.33	.35
Range	.33-1.00	.00-1.00	.33-1.00	.33-1.00	.33-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

FACTOR: GLASS 2- Wire Connection to Glass		Posttest 2 items: 6, 12, 17			
	CP	CCCS	CCCSW	CCCSWPIG	OVERALL MEAN
N	29	31	28	28	116
X	.81	.79	.75	.79	.78
SD	.33	.36	.31	.32	.33
Range	.33-1.00	.00-1.00	.33-1.00	.33-1.00	.33-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

Legend:

Factor scores have been converted to proportions

## Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 2 cont. Proportion correct: Electrical Circuits Posttest 1 and 2 factors for each treatment.

FACTOR:	SERIES - Series Circuit				Posttest 1 items: 21, 25	OVERALL MEAN
	CP	CCCS	CCCSW	CCCSWPIG		
N	29	31	28	28		116
X	.79	.68	.75	.73		.70
SD	.37	.44	.42	.40		.39
Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00		.00-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00		.00-1.00

FACTOR:	SERIES 2- Series Circuit				Posttest 2 items: 21, 25	OVERALL MEAN
	CP	CCCS	CCCSW	CCCSWPIG		
	29	31	28	28		116
X	.64	.60	.66	.84		.64
SD	.40	.50	.47	.31		.41
Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00		.00-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00		.00-1.00

Legend:

Factor scores have been converted to proportions

## Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 2 cont. Proportion correct: Electrical Circuits Posttest 1 and 2 factors for each treatment.

FACTOR:	SINK - Single Wire Connection			Posttest 1 items 1, 2, 3, 4, 5	OVERALL MEAN
	CP	CCCS	CCCSW	CCCSWPIG	
N	29	31	28	28	116
X	.70	.90	.91	.86	.85
SD	.33	.22	.21	.21	.28
Range	.00-1.00	.20-1.00	.20-1.00	.20-1.00	.00-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

FACTOR:	SINK 2- Single Wire Connection			Posttest 2 items 1, 2, 3, 4, 5	OVERALL MEAN
	CP	CCCS	CCCSW	CCCSWPIG	
N	29	31	28	28	116
X	.62	.85	.87	.90	.80
SD	.36	.26	.30	.14	.35
Range	.00-1.00	.20-1.00	.20-1.00	.20-1.00	.00-1.00
Possible Range	.00-1.00	.00-1.00	.00-1.00	.00-1.00	.00-1.00

Legend:

Factor scores have been converted to proportions

## Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 3 Correlation coefficients: Electrical Circuits Posttest 1 and 2 factors

	BULB	BULB2	CBULB	CBULB2	GLASS	GLASS2	SERIES	SERIES2	SINK	SINK2
BULB										
BULB2	.67**									
CBULB	.07	-.11								
CBULB2	.20*	.04	.75**							
GLASS	.38**	.34**	.14	.07						
GLASS2	.05	.28**	-.02	.07	.53**					
SERIES	.13	-.05	.31**	.38**	.08	-.02				
SERIES2	.07	-.05	.33**	.35**	.20*	.14	.53*			
SINK	.09	-.02	.10	.11	.05	.00	.14	.24*		
SINK2	.02	-.02	.16	.18	.07	.01	.10	.28**	.83**	

\*  $p < .05$

\*\*  $p < .01$

Legend:

Factors

Names for Electrical Circuits Posttest 1 factors -BULB, CBULB, GLASS, SERIES, SINK

Names for Electrical Circuits Posttest 2 factors - BULB 2, CBULB 2, GLASS 2, S SERIES 2, S SINK 2

BULB and BULB2 - connection to the bulb sub-test; CBULB and CBULB2 - correct connection with 1 bulb sub-test; GLASS and GLASS2 - wire connection to glass sub-test; SERIES and SERIES2 - series circuit sub-test; SINK and SINK2 - single wire connection sub-test

Table 4a. Multiple analysis of variance: Treatment and Electrical Circuits  
Posttest 1 factors\*\* with (EI)<sup>2</sup> as a covariate.

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARES	F	SIG. OF F
Covariate	2.92	1	2.92	16.50	<.01*
TMT	.35	3	.12	.66	.58
Subjects/TMT	18.57	105	.18		
Factors	15.51	4	3.88	37.93	<.01*
TMT x Factors	2.65	12	.22	2.16	.01*
Subjects x Factors/TMT	43.35	424	.10		

\*  $p < .05$

\*\*Means and standard deviations are presented in Table 5.

Post-hoc analyses of variance are presented in Appendix C Table 1.

Table 4b. Multiple analysis of variance: Treatment and Electrical Circuits  
Posttest 2 factors\*\* with (EI)<sup>2</sup> as a covariate.

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARES	F	SIG. OF F
Covariate	1.76	1	1.76	9.00	<.01*
TMT	.07	3	.02	.12	.95
Subjects/TMT	20.53	105	.20		
Factors	15.20	4	3.80	34.42	<.01*
TMT x Factors	2.72	12	.23	2.05	.02*
Subjects x Factors/TMT	46.82	424	.11		

\*  $p < .05$

\*\*Means and standard deviations are presented in Table 5.

Post-hoc analyses of variance are presented in Appendix C Table 1.

#### Legend:

TMT - Treatments

CP - Computer-based didactic lesson control group; CCCS - Conceptual Change Computer Simulation; CCCSW - Conceptual Change Computer Simulation and Reflective Writing; CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Factors - Five sub-tests of the Electrical Circuits Posttest.

(BULB - connection to the bulb sub-test; CBULB - correct connection with 1 bulb sub-test; SERIES - series circuit sub-test; GLASS - wire connection to glass sub-test; SINK - single wire connection sub-test)

Table 5. Post-hoc one way analysis and means and standard deviations: Proportion correct on Electrical Circuits Posttest 1 and 2 factors for each treatment.

Treatment	N	Conceptual Understanding		BULB		CBULB		GLASS		SERIES		SINK	
		X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
Posttest 1													
CP	29	16.14	5.31	.66 <sup>a</sup>	.36	.45 <sup>a</sup>	.36	.77 <sup>a</sup>	.34	.79 <sup>a</sup>	.37	.70 <sup>a</sup>	.33
CCCS	31	14.65	4.14	.40 <sup>b</sup>	.37	.38 <sup>a</sup>	.35	.67 <sup>a</sup>	.38	.68 <sup>a</sup>	.44	.90 <sup>b</sup>	.22
CCCSW	28	15.25	5.06	.39 <sup>b</sup>	.37	.45 <sup>a</sup>	.38	.71 <sup>a</sup>	.35	.75 <sup>a</sup>	.42	.91 <sup>b</sup>	.21
CCCSWPIG	28	15.11	4.07	.30 <sup>b</sup>	.31	.48 <sup>a</sup>	.42	.77 <sup>a</sup>	.33	.73 <sup>a</sup>	.40	.86 <sup>b</sup>	.21
Posttest 2													
CP	29	16.00	5.33	.59 <sup>a</sup>	.38	.51 <sup>a</sup>	.39	.81 <sup>a</sup>	.33	.64 <sup>a</sup>	.40	.62 <sup>a</sup>	.36
CCCS	31	15.13	4.72	.41 <sup>ab</sup>	.40	.39 <sup>a</sup>	.35	.79 <sup>a</sup>	.36	.60 <sup>a</sup>	.50	.85 <sup>b</sup>	.26
CCCSW	28	15.61	5.96	.33 <sup>ab</sup>	.38	.46 <sup>a</sup>	.39	.75 <sup>a</sup>	.31	.66 <sup>a</sup>	.47	.87 <sup>b</sup>	.30
CCCSWPIG	28	16.29	4.25	.34 <sup>b</sup>	.34	.45 <sup>a</sup>	.41	.79 <sup>a</sup>	.32	.84 <sup>a</sup>	.31	.90 <sup>b</sup>	.14

In a column, means with different superscripts are significantly different by the Student Newman-Kuels test .05 level.

**Legend:**

**Factors**

BULB - connection to the bulb sub-test; CBULB - correct connection with 1 bulb sub-test

SERIES - series circuit sub-test; GLASS - wire connection to glass sub-test; SINK - single wire connection sub-test

**Treatments**

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction



**APPENDIX C: POST-HOC ANALYSES TABLES**

Table 1 Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 1 factor BULB by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	2.03	3	.68	5.34	<.01*
Within groups	14.18	112	.13		

\*Student Newman-Kuels Procedure used at .05 level  
Analysis indicated a significant difference between CP treatment and CCCSWPIG treatments

Legend:

Factor

BULB - Connection to bulb

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 2 factor BULB2 by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	1.23	3	.41	2.90	.04*
Within groups	15.80	112	.14		

\*Student Newman-Kuels Procedure used at .05 level

Analysis indicated a significant difference between CP treatment and CCCSWPIG treatments

Legend:

Factor

BULB2- Connection to bulb

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 1 factor CBULB by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	.18	3	.06	.43	.74
Within groups	15.96	112	.14		

\*Student Newman-Kuels Procedure used at .05 level

Legend:

Factor

CBULB - Correct connection with 1 bulb

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 2 factor CBULB2 by treatment

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	.21	3	.07	.48	.70
Within groups	16.55	112	.15		

\*Student Newman-Kuels Procedure used at .05 level

Legend:

Factor

CBULB2 - Correct connection with 1 bulb

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 1 factor GLASS by treatment

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	.23	3	.08	.64	.59
Within groups	13.53	112	.12		

\*Student Newman-Kuels Procedure used at .05 level

Legend:

Factor

GLASS - Wire connection to glass

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 2 factor GLASS2 by treatment

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	.04	3	.01	.14	.94
Within groups	12.20	112	.11		

\*Student Newman-Kuels Procedure used at .05 level

Legend:

Factor

GLASS2 - Wire connection to glass

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 1 factor SERIES by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	.21	3	.07	.42	.74
Within groups	18.52	112	.17		

\*Student Newman-Kuels Procedure for .05 level

Legend:

Factor

SERIES - series circuit

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction



Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 2 factor SERIES2 by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	.99	3	.33	1.82	.15
Within groups	20.21	112	.18		

\*Student Newman-Kuels Procedure used at .05 level

Legend:

Factor

SERIES2 - series circuit

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 1 factor SINK by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	.79	3	.26	4.34	<.01*
Within groups	6.80	112	.06		

\*Student Newman-Kuels Procedure used at .05 level

Analysis indicated a significant difference between CP treatment and experimental treatments (CCCS, CCCSW, CCCSWPIG).

Legend:

Factor

SINK - single wire connection

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

Table 1 cont. Post-hoc one way analysis of variance\*: Electrical Circuits  
Posttest 2 factor SINK2 by treatment.

SOURCE OF VARIATION	SUM OF SQUARES	df	MEAN SQUARES	F RATIO	F PROB.
Between groups	1.41	3	.47	6.22	<.01*
Within groups	8.46	112	.08		

\*Student Newman-Kuels Procedure used at .05 level

Analysis indicated a significant difference between the CP treatment and the experimental treatments (CCCS, CCCSW, CCCSWPIG).

Legend:

Factor

SINK2 - single wire connection

Treatments

CP - Computer-based didactic lesson control group

CCCS - Conceptual Change Computer Simulation

CCCSW - Conceptual Change Computer Simulation and Reflective Writing

CCCSWPIG - Conceptual Change Computer Simulation, Writing, and Peer Interaction

**APPENDIX D.    ELECTRICITY INTEREST AND EXPERIENCE  
INVENTORY AND ELECTRICAL CIRCUITS  
POSTTEST**

**ELECTRICITY INTEREST AND EXPERIENCE QUESTIONNAIRE**

The purpose of this questionnaire is to find out how much experience and interest you have in the topic of electricity. Please answer each item on the questionnaire by marking the corresponding circle on your answer sheet. Using a pencil, be sure to color in the appropriate circle completely. Erase all stray marks. Please do not mark on the test booklet itself; it will be used again in the future.

For identification purposes, enter the last four digits of your social security number in the 3rd - 6th location of the section entitled "identification number". Please skip the first two spaces in this section. ( for example, \_ \_ \_ \_ \_ ).

If you have questions concerning the questionnaire, raise your hand and a proctor will assist you. When you have completed the test, turn it in with your answer sheet.

**ELECTRICITY INTEREST AND EXPERIENCE INVENTORY**

1. What is your gender?
  - a. male      b. female
2. What is your academic year?
  - a. freshman      b. sophomore      c. junior      d. senior
  - e. other
3. Are you majoring in education?
  - a. yes (go to item 4)
  - b. no (go to item 7)
4. At what level are you planning to teach?
  - a. elementary
  - b. secondary
5. What grade level are you interested in teaching?
  - a. grades pre-K - 3      b. grades 4-6
  - c. grades K - 6      d. middle school/ junior high
  - e. high school      f. other
6. What is your area of emphasis (if elementary) or academic major (if secondary)?
  - a. math (go to item 10)
  - b. science (go to item 10)
  - c. social studies (go to item 10)
  - d. physical education (go to item 10)
  - e. language arts (go to item 10)
  - f. general (go to item 10)
  - g. other (go to item 10)
7. Are you a physical or biological science major?
  - a. yes (go to item 8)
  - b. no (go to item 10)
8. What is your area of emphasis?
  - a. agriculture      b. chemistry      c. physics
  - d. biology      e. earth science      f. other

**go to item 10**

9. What is your category of major?
- |                        |                               |
|------------------------|-------------------------------|
| a. engineering         | b. family or consumer science |
| c. veterinary medicine | d. social science             |
| e. humanities          | f. arts or design             |
| g. mathematics         | h. business                   |
| i. agriculture         | j. none of the above          |
10. What is your age?
- a. 18 or less    b. 19-21    c. 22-25    d. 25 or older
11. With which type of computer system are you most familiar?
- a. Macintosh    b. Apple    c. IBM/Zenith/MS DOS  
d. other    e. I've never used a computer.
12. Have you ever used a mouse to access a computer system?
- a. yes    b. no
13. How comfortable are you with using a mouse and computer?
- a. very comfortable  
b. comfortable  
c. somewhat uncomfortable  
d. very uncomfortable
14. How many semesters of physics did you take in high school?
- a. 0    b. 1    c. 2    d. 3    e. 4 or more
15. Did you ever build electronic or electrical toys as a child or adolescent?
- a. never    b. once or twice  
c. occasionally (3 or 4 times)    d. frequently (more than 4 times)
16. How many formal educational experiences other than in high school or college have you taken that involved training in electricity? (eg. mail order courses, community college courses, etc.)
- a. 0    b. 1    c. 2    d. 3    e. 4 or more
17. How many physics courses have you taken in college?
- a. 0    b. 1    c. 2    d. 3    e. 4 or more
18. How many electrical or computer engineering courses have you taken in college?
- a. 0    b. 1    c. 2    d. 3    e. 4 or more

20. How often have you taken apart electrical toys or appliances?
- |                                |                                   |
|--------------------------------|-----------------------------------|
| a. never                       | b. once or twice                  |
| c. occasionally (3 or 4 times) | d. frequently (more than 4 times) |

Using a scale where 1 = not at all interested and 10 = extremely interested, rate your level of interest for each item below. Please fill in the circle for the corresponding number.

1	2	3	4	5	6	7	8	9	10
Not at all interested									Extremely interested

21. How interested were you in physics in high school?
22. How interested are you in taking a physics course in college?
23. How interested are you in taking an electrical or computer engineering course in college?
24. As a child and adolescent, how interested were you in building electronic or electrical toys?
25. As a child and adolescent, how interested were you in taking apart electronic or electrical toys?
26. How interested were you as a child or adolescent in taking a formal educational experience other than in high school or college that involves training in electricity? (eg. mail order courses, community college courses, etc.)
27. Currently, how interested are you in taking a formal educational experience other than in high school or college that involves training in electricity? (eg. mail order courses, community college courses, etc.)



28. How interested are you in doing any electrical repair work such as appliances, house wiring, or car wiring?
29. How interested as a child or adolescent were you in connecting stereo components?
30. Currently, how interested are you in connecting stereo components?
31. How interested were you as a child or adolescent in taking apart electrical appliances?
32. Currently, how interested are you in taking apart electrical appliances?

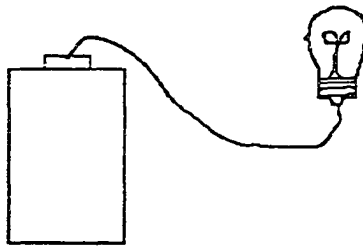
**Electricity Test Instructions**

This is a test over the material on electricity that you have studied. Please answer the multiple choice questions on the answer sheet by completely fill in the appropriate circle. Please use a pencil to complete the test and do not write on the test booklet.

Put your section number and the last four digits of your social security number in the identification number section of the answer sheet. Also, fill in the corresponding circles for your identification number.

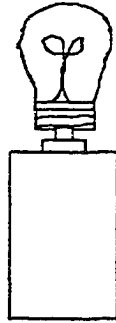
If you have questions during the test, either raise your hand or bring the test booklet to the facilitator. When you are done with the test, please bring your test booklet and answer sheet to the facilitator.

1. Will the bulb in this diagram light?



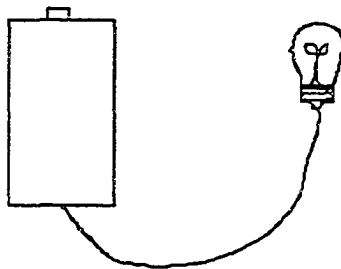
- a. Yes, because electricity can flow from the bump on the top of the battery to the light bulb directly.
- b. Yes, because any connection between the battery and the light bulb will cause the bulb to light.
- c. No, because the wire is connected to the wrong part of the light bulb.
- d. No, because electricity cannot flow in the circuit.
- e. No, because electricity can only flow out of the other side of the battery, not the side the wire is connected to.

2. Will the bulb in this diagram light?



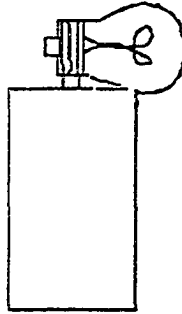
- a. Yes, because electricity can flow from the bump on the top of the battery to the light bulb directly.
- b. Yes, because any connection between the battery and the light bulb will cause the bulb to light.
- c. No, because the wire is connected to the wrong part of the light bulb.
- d. No, because electricity cannot flow in the circuit.
- e. No, because electricity can only flow out of the other side of the battery, not the side the wire is connected to.

3. Will the bulb in this diagram light?



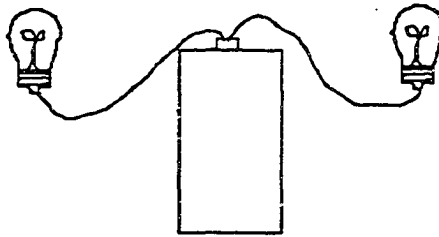
- a. Yes, because electricity can flow from the bottom of the battery to the light bulb directly.
- b. Yes, because any connection between the battery and the light bulb will cause the bulb to light.
- c. No, because the wire is connected to the wrong part of the light bulb.
- d. No, because electricity cannot flow in the circuit.
- e. No, because electricity can only flow out of the other side of the battery, not the side the wire is connected to.

4. Will the bulb in this diagram light?



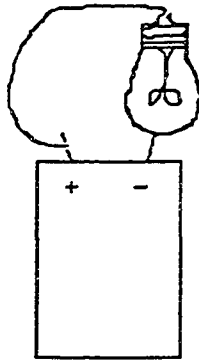
- a. Yes, because electricity can flow from the bump on the top of the battery to the light bulb directly.
- b. Yes, because any connection between the battery and the light bulb will cause the bulb to light.
- c. No, because the bulb is connected to the wrong part of the battery.
- d. No, because electricity cannot flow in the circuit.
- e. No, because electricity can only flow out of the other side of the battery, not the side the wire is connected to.

5. Will the bulbs in this diagram light?



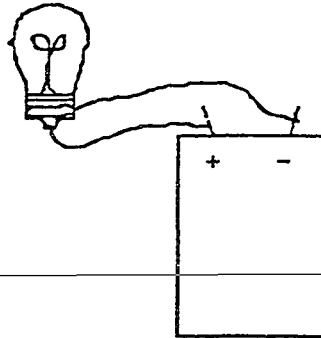
- a. Yes, because electricity can flow from the bump on the top of the battery to the light bulbs directly.
- b. Yes, because any connection between the battery and the light bulbs will cause the bulb to light.
- c. No, because the wires are connected to the wrong part of the light bulbs.
- d. No, because electricity cannot flow in the circuit.
- e. No, because electricity can only flow out of the other side of the battery, not the side the wires are connected to.

6. Will the bulb in this diagram light?



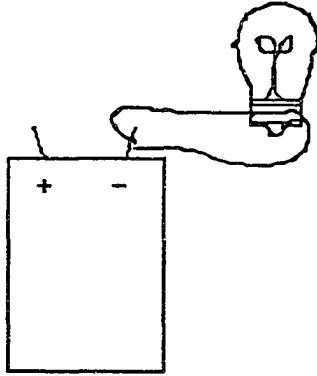
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

7. Will the bulb in this diagram light?



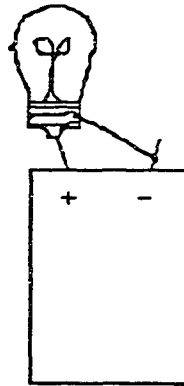
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

8. Will the bulb in this diagram light?



- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

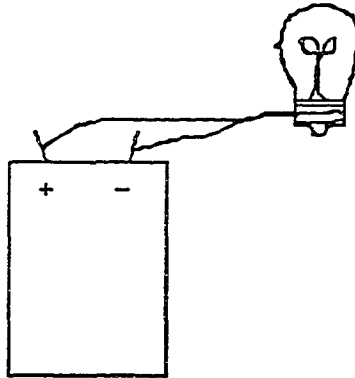
9. Will the bulb in this diagram light?



- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

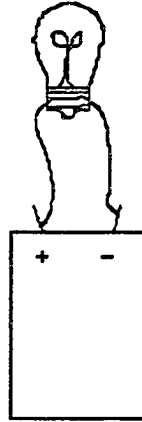


10. Will the bulb in this diagram light?



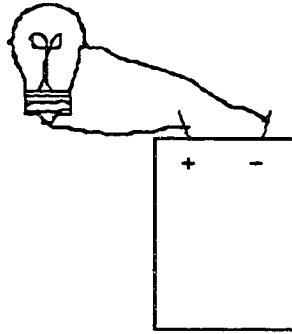
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

11. Will the bulb in this diagram light?



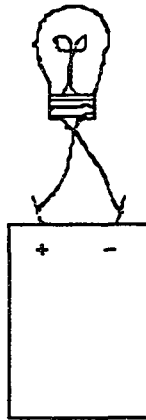
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

12. Will the bulb in this diagram light?



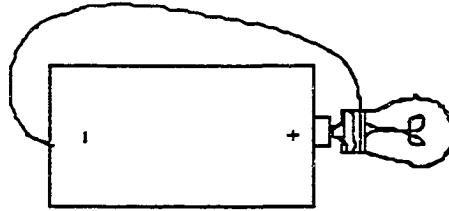
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

13. Will the bulb in this diagram light?



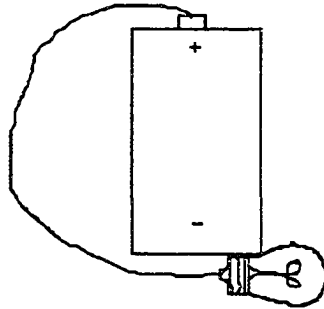
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

14. Will the bulb in this diagram light?



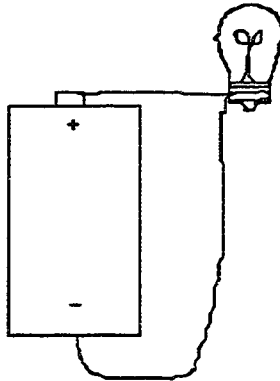
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

15. Will the bulb in this diagram light?



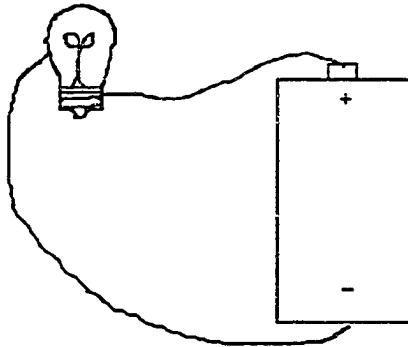
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

16. Will the bulb in this diagram light?



- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

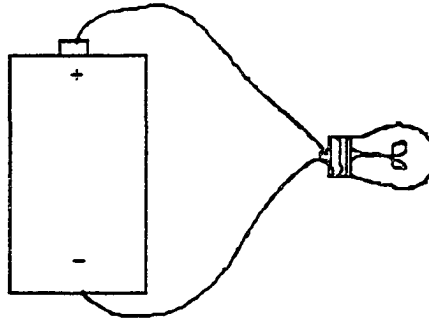
17. Will the bulb in this diagram light?



- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

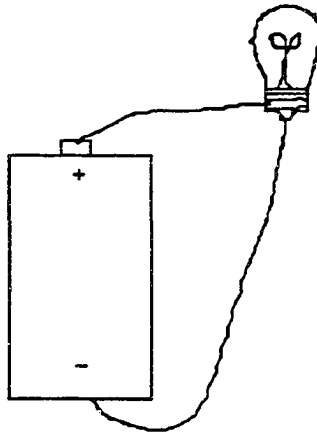


18. Will the bulb in this diagram light?



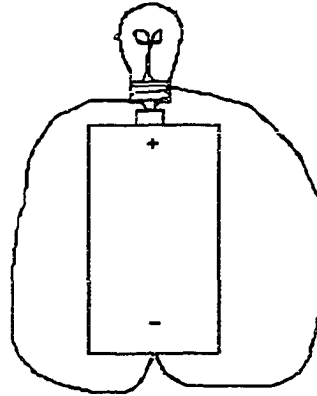
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

19. Will the bulb in this diagram light?



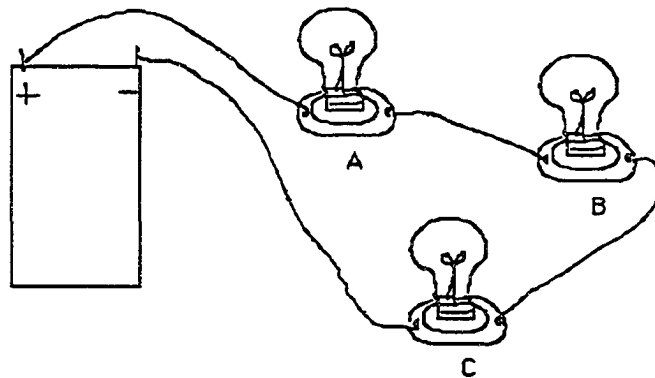
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

20. Will the bulb in this diagram light?



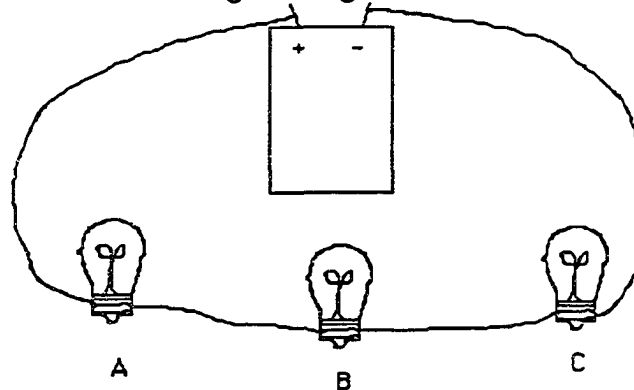
- a. Yes, because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulb and the conflict of the positive and negative electricities causes the bulb to light.
- b. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light.
- c. Yes, because any single wire connection between the battery and the light bulb will cause the bulb to light.
- d. Yes, because the passing through of current moving from one terminal through the light bulb and back to the other battery terminal will cause the light bulb to light however, less current returns to the battery than originally passed through the first terminal.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb.
- g. No, because there is no electricity in this circuit.

21. Will the bulbs in this diagram light?



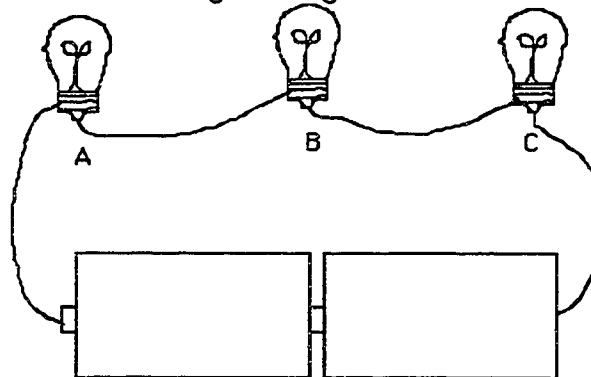
- a. Yes, all bulbs light because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulbs and the conflict of the positive and negative electricities causes the bulbs to light.
- b. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminal will cause the light bulbs to light but bulb A will be brighter than bulb B or bulb C because it gets more current.
- c. Yes, because any single wire connection between the battery and the light bulbs will cause the bulbs to light.
- d. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminal will cause all of the light bulbs to light.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulb holders.
- g. No, because there is no electricity in this circuit.

22. Will the bulbs in this diagram light?



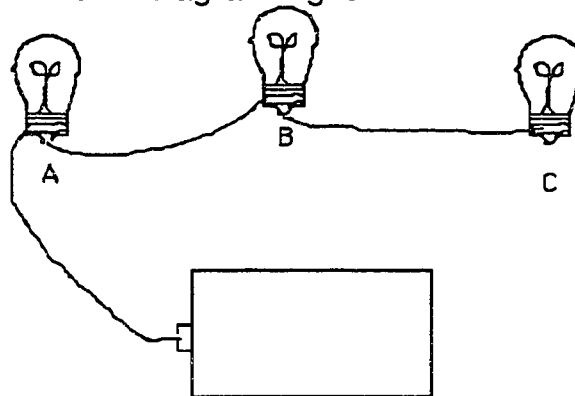
- a. Yes, all bulbs light because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulbs and the conflict of the positive and negative electricities causes the bulbs to light.
- b. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminal will cause the light bulbs to light but bulb A will be brighter than bulb B or bulb C because it gets more current.
- c. Yes, because any single wire connection between the battery and the light bulbs will cause the bulbs to light.
- d. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminal will cause all of the light bulbs to light.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulbs.
- g. No, because there is no electricity in this circuit.

23. Will the bulbs in this diagram light?



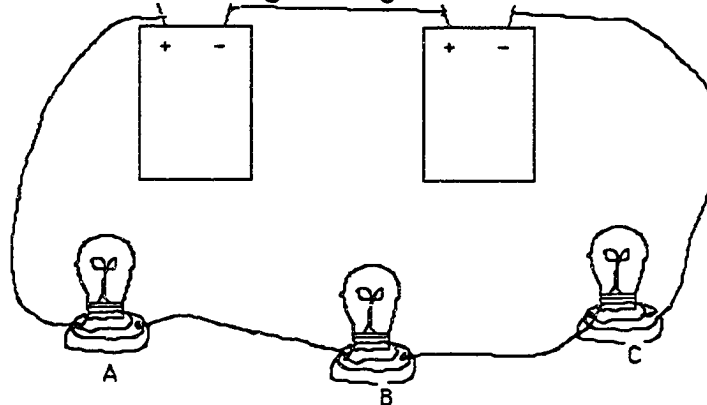
- a. Yes, all bulbs light because positive electricity from the positive terminals and negative electricity from the negative terminals meet at the light bulbs and the conflict of the positive and negative electricities causes the bulbs to light.
- b. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminal will cause the light bulbs to light but bulb A will be brighter than bulb B or bulb C because it gets more current.
- c. Yes, because any single wire connection between the batteries and the light bulbs will cause the bulbs to light.
- d. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminals will cause all of the light bulbs to light.
- e. No, because the wire is connected to the wrong part of the batteries.
- f. No, because the batteries are connected to the wrong part of the light bulbs.
- g. No, because there is no electricity in this circuit.

24. Will the bulbs in this diagram light?



- a. Yes, all bulbs light because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulbs and the conflict of the positive and negative electricities causes the bulbs to light.
- b. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminal will cause the light bulbs to light but bulb A will be brighter than bulb B or bulb C because it gets more current.
- c. Yes, because any single wire connection between the battery and the light bulbs will cause the bulbs to light.
- d. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminal will cause all of the light bulbs to light.
- e. No, because the wire is connected to the wrong part of the battery.
- f. No, because the battery is connected to the wrong part of the light bulbs.
- g. No, because there is no electricity in this circuit.

25. Will the bulbs in this diagram light?



- a. Yes, all bulbs light because positive electricity from the positive terminal and negative electricity from the negative terminal meet at the light bulbs and the conflict of the positive and negative electricities causes the bulbs to light.
- b. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminals will cause the light bulbs to light but bulb A will be brighter than bulb B or bulb C because it gets more current.
- c. Yes, because any single wire connection between the batteries and the light bulbs will cause the bulbs to light.
- d. Yes, because the passing through of current moving from one terminal through bulb A, bulb B, and bulb C and back to the other battery terminals will cause all of the light bulbs to light.
- e. No, because the wire is connected to the wrong part of the batteries.
- f. No, because the batteries are connected to the wrong part of the light bulb holders.
- g. No, because there is no electricity in this circuit.

26. A lamp having a resistance of 10 ohms is connected across a 15 - V battery with 2 A current. What resistance must be connected in series with the lamp to reduce the current to .5A?

- a. 40 ohms
- b. 20 ohms
- c. 10 ohms
- d. 80 ohms



27. What would be the voltage is a 25-ohm heater connected in a circuit with .24 amperes current?

- a. 104 V
- b. 6 V
- c. 0.0096 V
- d. 25.24 V

28. A light bulb with a resistance of 140 ohms is connected to a source having potential difference of 120 volts. What current will flow?

- a. 0.860 A
- b. 1.167 A
- c. 260 A
- d. 16800 A

29. A circuit with a 36-ohm resistance is connected to 12 -V battery. Find the current in the circuit.

- a. 3.00 A
- b. 0.33 A
- c. 432 A
- d. 48 A

**APPENDIX E. FACILITATOR INSTRUCTIONS, TREATMENT  
DIRECTIONS, AND CCCSWPIG FACILITATOR  
PROCEDURES AND MATERIALS**

- E1: Facilitator Instructions**
- E2: Treatment Directions**
- E3: CCCSWPIG Facilitator Procedures and Materials**
- E4: Computer Screens viewed in groups by CCCSWPIG treatment**

E1: Facilitator Instructions

### Facilitator Instructions

**\*\*\* If you change the mode on a stack, be sure to return it to the original mode at the end of session**

1. Before class, pick up treatment packet and check computers in assigned room

\_\_\_\_\_ Electricity 1 folder is showing and has electricity 1 stack

\_\_\_\_\_ Electricity 2 folder is showing and has electricity 2 stack

2. Report to the 301 classroom to pick up students and test packets.
3. Go to assigned experiment rooms, have students sit at computers, and write section number on the board.
4. Start videotape (make sure camera can see all students at computers)
5. Pass out scratch paper or journals (instruct students not to flip through journal)
6. Read instructions to students (BE ENTHUSIASTIC)
7. Read and do mouse directions (if needed); instruct students on which Folder to use
8. RECORD START TIME (start clock when computer activities begin)
9. Assist students as needed; do not give answers to content questions, instead direct their thinking to find their own answers.
10. Monitor computer time, (remember- 45 minutes minimum and 1 hour maximum)
11. RECORD COMPUTER FINISH TIME OF LAST STUDENT.
12. Give students ID cards, test and answer sheet (remember, 40 minutes are allowed for test)
13. Collect ID cards and answer sheet, and stop video -- put in treatment packet  
Put Tests and pencils in test packet and return to both envelopes to 301 room
14. Return computers and room to original state
  - "Quit" Hypercard (Apple - Q)
  - close folder(s)
  - leave computers on

\* If you use a function Key to relocate a student, hit F14 to cancel facilitator prompts

**\*\*\* If you change the mode on a stack, be sure to return it to the original mode at the end of session**

Supplies

- Posttest booklets and pencils (on instructor table in front of room)
- Posttest envelope with instructor's name (in box near front of room)
  - answer sheets
  - ID cards
- America 2000 pamphlets (in box near front of room)

TASKS

- I. After regular lesson, briefly review with students last week's activities
- II. Explain that we are interested in their long-term learning as a result of the the computer-based instruction, thus we would like them to complete one more posttest.
- III. Stress the need for the students to do their best on the posttest in order for the researchers to understand how computers help them learn.
- IV. Pass out answer sheets & ID cards
- V. Explain directions for completing the IDENTIFICATION SECTION of answer sheet.

The ID number the students enter on to the answer sheet should match the number written on the ID card. The final product should be a six-digit number (2 digits from section number & last four digits of social security number) with no spaces between the numbers. The six digits should be written in slots A-F on the answer sheet and the appropriate circles colored in.

for example, I was in Section 11 and my ss # is 479-02-7986  
my ID number is 1 1 7 9 8 6

**\*\*\*STRESS GETTING THE CORRECT NUMBERS IN THE CORRECT LOCATIONS OF THE ID SECTION**

- VI. Pass out posttest booklets and have students begin
  - VII. When students complete the test, have them turn in test booklet, answer sheet and ID card
- \*\*\*AS STUDENTS TURN IN ANSWER SHEETS, CHECK EACH ID SECTION TO MAKE SURE IT HAS BEEN COMPLETED CORRECTLY**
- VIII. As a "Thank You" for the students, they may each take a copy of **America 2000** as they leave
  - IX. Return answer sheets and ID cards to labeled envelope & stack test booklets and pencils on instructor's table for the next class.

**E2: Treatment Directions**

## Treatment Instructions

### Directions for Computer Presentation (CP)

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

Today's activity is an individual computer-based instructional experience. The instruction will appear on the computer screen, so read each screen carefully. Throughout the computer-based instruction you may hear different sounds from the computers in the room. Please ignore the sounds you hear from other computers and concentrate on your own. Don't worry that you are not keeping up with your neighbor as everyone will be in a slightly different place. Remember this is an individual instructional activity, so please do not consult with your neighbor. Focus on your own work.

Throughout the electricity lesson, questions or directions may pop-up on the screen. You **DO NOT** have to write out the answers to these questions. Instead, critically think through the answers to the questions/directions that pop-up and **then** click "OK" to continue. In addition to the questions that may pop-up on the screen, you may be directed to perform some basic arithmetic calculations. Please perform all of the calculations. You can use the paper provided for this purpose. Again, you do not have to write out the answers to the questions, but you **must** critically think through your answer before clicking "OK" to continue. Please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience. Last, it may seem as though you are at the end of the lesson before you actually are; when the words "Thank You" appear on the screen you have completed the lesson.

If you have questions about the lesson, please raise your hand and I will assist you. Take your time going through the system and try to learn as much as you can. You **must** spend at least 45 minutes on the lesson and but no more than 1 hour. When you complete the lesson, please bring your scratch paper to the front and pick up a test. You will have 40 minutes to complete the test.

**Mouse Directions - Electricity Folder # 1**  
**(for treatment CP only)**

How many of you are familiar with a Macintosh computer and a mouse?

To assist you in operating the computer-based electricity lesson, we will go over the operations of a mouse. The mouse is the device you will use to access information on the computer. The mouse is located on the right side of the key board and is connected to the computer by a thin cable. When the cable connection on the mouse is headed toward the computer, the mouse is right-side-up. Pick up the mouse and look at it's bottom. See the ball on the mouse? The mouse uses the ball to move an arrow around the screen of the computer. Move the ball in a circle and look at the screen. You should see an arrow moving around. This is how the mouse accesses information in the computer. Set the mouse down and use it to move the arrow around the screen. This is how a mouse works.

There are 3 skills you need to use a mouse and the electricity lesson. They are Pointing, Clicking and Dragging. Pointing is the process of moving the arrow to a specific location or object on the screen. Move the arrow (via the mouse) to the hard drive in the upper right corner. Place the arrow directly on the hard drive label. Point directly to the first letter on the label. This is pointing. Pointing is moving the arrow to a specific location or object on the screen.

Clicking is the process of accessing an object or information in the computer. Notice the rectangle near the top of the mouse, this is the mouse button and is used for clicking. You press down on the rectangle to "click on" and access an object. Before clicking on an object, you must "Point" to it. Point to the rectangle above the hard drive label on your screen. This is the Hard Drive. Click on the hard drive. Notice it turns dark; you have selected and can access the hard drive. To "de-select" the hard drive, click anywhere on the screen except on the hard drive. Click off of the hard drive and click on the folder "Electricity 1". Now click off of "Electricity 1". This is clicking. You click to access an object or get information in the computer.

The last skill you need to learn is Dragging. Dragging is the process of moving an object around the screen. In order to drag an object, you must click on the object , hold down the mouse button, and move the mouse. Click and hold on the hard drive, now move the mouse around. Drag the hard drive to the top left corner of the screen. This is dragging. Now "DRAG" the hard drive to the center of the screen.

**Practice**

Click on the folder "Electricity 1" Point to the folder "Electricity 2". Now drag the hard drive back to the top right corner. You've got it, Pointing, Clicking and Dragging- the three skills you will need for this lesson. Now click twice on the **Electricity 1 folder**. The folder should open up. Point to the icon labeled "Electricity 1". Click twice on this icon to begin the computer lesson.



**Directions for Conceptual Change Computer Simulation (CCCS)**

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

Today's activity is an individual computer-based instructional experience. The instruction will appear on the computer screen, so read each screen carefully. Throughout the computer-based instruction you may hear different sounds from the computers in the room. Please ignore the sounds you hear from other computers and concentrate on your own. Don't worry that you are not keeping up with your neighbor as everyone will be in a slightly different place. Remember this is an individual instructional activity, so please do not consult with your neighbor. Focus on your own work.

Throughout the electricity lesson, questions or directions may pop-up on the screen. You **DO NOT** have to write out the answers to these questions. Instead, critically think through the answers to the questions/directions that pop-up and **then** click "OK" to continue. In addition to the questions that may pop-up on the screen, you may be directed to perform some basic arithmetic calculations. Please perform all of the calculations. You can use the paper provided for this purpose. Again, you do not have to write out the answers to the questions, but you **must** critically think through your answer before clicking "OK" to continue. Please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience. Last, it may seem as though you are at the end of the lesson before you actually are; when the words "Thank You" appear on the screen you have completed the lesson.

If you have questions about the lesson, please raise your hand and I will assist you. Take your time going through the system and try to learn as much as you can. You **must** spend at least 45 minutes on the lesson and but no more than 1 hour. When you complete the lesson, please bring your scratch paper to the front and pick up a test. You will have 40 minutes to complete the test.

**Directions for Conceptual Change Computer Simulation & Writing**  
**(CCCSW)**

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

Today's activity is an individual computer-based instructional experience. The instruction will appear on the computer screen, so read each screen carefully. Throughout the computer-based instruction you may hear different sounds from the computers in the room. Please ignore the sounds you hear from other computers and concentrate on your own. Don't worry that you are not keeping up with your neighbor as everyone will be in a slightly different place. Remember this is an individual instructional activity, so please do not consult with your neighbor. Focus on your own work.

Throughout the electricity lesson, numbered questions or directions may pop-up on the screen. Please find the corresponding number and question in your journal and write the answer. Some questions have more than one part (for example, 1a, 1b, and 1c). Answer ***every*** part of the question before going on. Click "OK" to continue ***only*** after you have answered all parts of the question in your journal. In addition to the questions that may pop-up on the screen, you may be directed to perform some basic arithmetic calculations. Please perform ***all*** of the calculations. You can use the space in your journal for this purpose. If you are asked the same question more than once, please write out the answer each time you are asked.

Please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience. Last, it may seem as though you are at the end of the lesson before you actually are; when the words "Thank You" appear on the screen you have completed the lesson.

If you have questions about the lesson, please raise your hand and I will assist you. Take your time going through the system and try to learn as much as you can. You ***must*** spend at least 45 minutes on the lesson and but no more than 1 hour. When you complete the lesson, please bring your journal to the front and pick up a test. You will have 40 minutes to complete the test.

**Mouse Directions - Electricity Folder # 2**  
**(for treatments CCCS & CCCSW only)**

How many of you are familiar with a Macintosh computer and a mouse?

To assist you in operating the computer-based electricity lesson, we will go over the operations of a mouse. The mouse is the device you will use to access information on the computer. The mouse is located on the right side of the key board and is connected to the computer by a thin cable. When the cable connection on the mouse is headed toward the computer, the mouse is right-side-up. Pick up the mouse and look at it's bottom. See the ball on the mouse? The mouse uses the ball to move an arrow around the screen of the computer. Move the ball in a circle and look at the screen. You should see an arrow moving around. This is how the mouse accesses information in the computer. Set the mouse down and use it to move the arrow around the screen. This is how a mouse works.

There are 3 skills you need to use a mouse and the electricity lesson. They are Pointing, Clicking and Dragging. Pointing is the process of moving the arrow to a specific location or object on the screen. Move the arrow (via the mouse) to the hard drive in the upper right corner. Place the arrow directly on the hard drive label. Point directly to the first letter on the label. This is pointing. Pointing is moving the arrow to a specific location or object on the screen.

Clicking is the process of accessing an object or information in the computer. Notice the rectangle near the top of the mouse, this is the mouse button and is used for clicking. You press down on the rectangle to "click on" and access an object. Before clicking on an object, you must "Point" to it. Point to the rectangle above the hard drive label on your screen. This is the Hard Drive. Click on the hard drive. Notice it turns dark; you have selected and can access the hard drive. To "de-select" the hard drive, click anywhere on the screen except on the hard drive. Click off of the hard drive and click on the folder "Electricity 1". Now click off of "Electricity 1". This is clicking. You click to access an object or get information in the computer.

The last skill you need to learn is Dragging. Dragging is the process of moving an object around the screen. In order to drag an object, you must click on the object , hold down the mouse button, and move the mouse. Click and hold on the hard drive, now move the mouse around. Drag the hard drive to the top left corner of the screen. This is dragging. Now "DRAG" the hard drive to the center of the screen.

**Practice**

Click on the folder "Electricity 1" Point to the folder "Electricity 2". Now drag the hard drive back to the top right corner. You've got it, Pointing, Clicking and Dragging- the three skills you will need for this lesson. Now click twice on the **Electricity 2 folder**. The folder should open up. Point to the icon labeled "Electricity 2". Click twice on this icon to begin the computer lesson.

**Directions for Conceptual Change Computer Simulation, Writing, and  
Peer Interaction Group (CCCSWPIG)**

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system and cooperative groups to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

My name is Karen and I will be your facilitator. Lets start by introducing ourselves. Tell us your name and your favorite kind of ice cream.

Before we begin, I want to explain the kinds of activities we'll be doing during this lesson. As I mentioned, you will be working with a computer-based lesson on electricity. Throughout the electricity lesson, we will view computer presentations as a group, work on the computer individually, express your individual views concerning the content in your journal, and discuss your views with the group. Some of the questions require you to be creative and resourceful. It is important that everyone is an active participant and voices their viewpoint on the issues. *No one* wins unless *everyone* participates!

During this lesson we will go back and forth between group computer activities, individual computer activities and group discussions. I will inform you when it's time for individual activities and the computer will inform you when it is time to return to group activities by giving you a message that says, "Please wait for facilitator before continuing".

When we go through the computer activities, numbered questions or directions may pop-up on the screen. Please find the corresponding number and question in your journal and write the answer. Some questions have more than one part (for example, 1a, 1b, and 1c). Answer *every* part of the question before going on. Click "OK" to continue *only* after you have answered all parts of the question in your journal. In addition to the questions that may pop-up on the screen, you may be directed to perform some basic arithmetic calculations. Please perform all of the calculations. You can use the space in your journal for this purpose. If you are asked the same question more than once, please write out the answer each time you are asked.

Please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience.

If you have questions about the lesson, please raise your hand and I will assist you. Take your time going through the system and try to learn as much as you can. You must spend at least 45 minutes on the lesson and but no more than 1 hour. When you complete the lesson, please bring your journal to the front and pick up a test. You will have 40 minutes to complete the test.

**Mouse Directions - Electricity Folder # 2**  
**(for treatment CCCSWPIG only)**

How many of you are familiar with a Macintosh computer and a mouse?

To assist you in operating the computer-based electricity lesson, we will go over the operations of a mouse. The mouse is the device you will use to access information on the computer. The mouse is located on the right side of the key board and is connected to the computer by a thin cable. When the cable connection on the mouse is headed toward the computer, the mouse is right-side-up. Pick up the mouse and look at it's bottom. See the ball on the mouse? The mouse uses the ball to move an arrow around the screen of the computer. Move the ball in a circle and look at the screen. You should see an arrow moving around. This is how the mouse accesses information in the computer. Set the mouse down and use it to move the arrow around the screen. This is how a mouse works.

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The last skill you need to learn is Dragging. Dragging is the process of moving an object around the screen. In order to drag an object, you must click on the object , hold down the mouse button, and move the mouse. Click and hold on the hard drive, now move the mouse around. Drag the hard drive to the top left corner of the screen. This is dragging. Now "DRAG" the hard drive to the center of the screen.

**Practice**

Click on the folder "Electricity 1" Point to the folder "Electricity 2". Now drag the hard drive back to the top right corner. You've got it, Pointing, Clicking and Dragging- the three skills you will need for this lesson. Now click twice on the **Electricity Lesson** and turn this direction. We will begin up here as a group.

**E3: CCCSWPIG Facilitator Procedures and Materials**

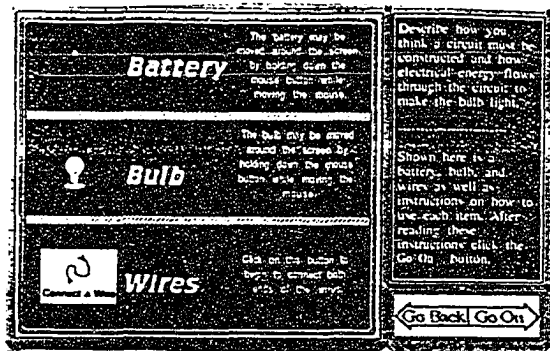
### CCCSWAP steps

1. Start students' computer simulations  
(they will stop at City screen)
2. Read treatment instructions
3. Start LCD simulation

#### 1st card of LCD simulation



#### Last card with audio - simulation instructions



4. Have students address question in their journals (if you push GO ON on LCD simulation, the question will appear on screen)
  1. Describe how you think a circuit must be constructed and how electrical energy flows through the circuit to make the bulb light.



5. Have students voice their <sup>164</sup>opinion on how a circuit must be constructed. Ask the following:

- How do you think a circuit must be built to make the bulb light?
- **How does current move in the circuit?**

*(Get them to voice their opinion and explain how current moves. Some will just agree with what others have said. Challenge them by asking if that's what they really wrote down.)*

*Some students will say "I don't know" tell them they must have some idea because they use it everyday! Try and get them to form an opinion.*

### **YOUR TASK: GET THEM TO EXPLAIN & THEN CLARIFY WHAT THEY SAY BY REITERATING IT**

6. Students return to individual computers and hit **F1** to test their idea. (Students will go through simulation and instruction --sink theory and/or clashing current--. At the end of clashing current, the computer will stop them.)

**\*\*\*Remember-**        **YOU MUST STOP STUDENTS AFTER THEY GET  
THROUGH CLASHING CURRENT**

7. When students start simulations, hit **F2** to move LCD simulation to next audio section (nature of electric circuits)

8. Have students discuss what they learned in the simulation. Ask the following:

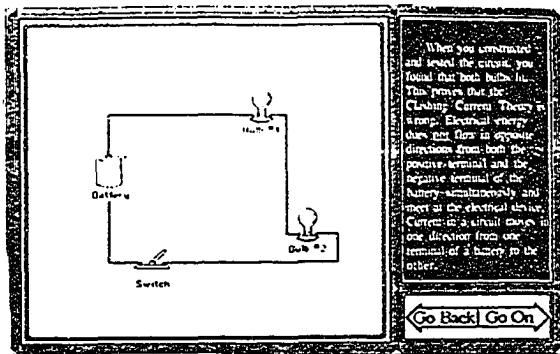
- What did you learn?
- According to the simulation, how must a circuit be constructed to cause the bulb to light?
- How many wires are needed?
- Where are the wires to be connected?
- How does current flow in the circuit? (which direction?)

9. Have students answer journal questions at the bottom of clashing current page.  
**-What did they learn about how a circuit must be built and how current flows**

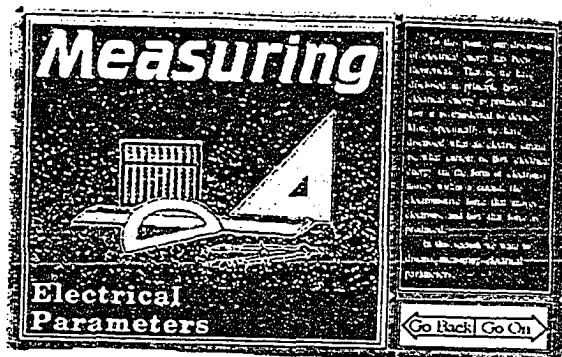
**-How is what you learned different from what you originally thought?**

10. Start LCD simulation

**1st audio card of Nature of Electricity section**



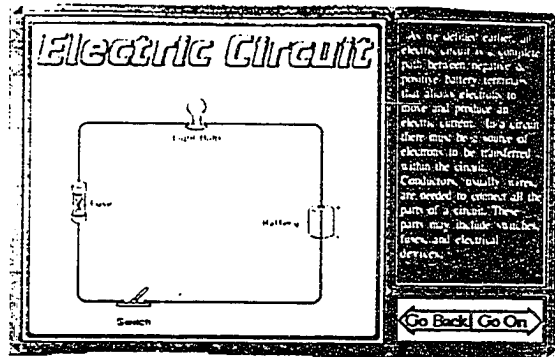
**Last audio card of Nature of Electricity section**



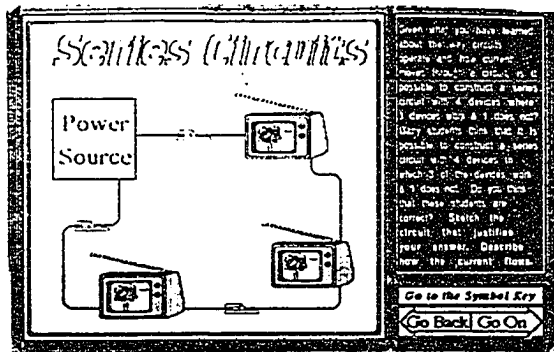
11. Have students push F2 to move to Measuring Electricity section.

12. Students will work through the Measuring Electricity Section on their own.
- The computer will direct them to write in their journals.
  - There will be no group discussion for this section.
13. When students start simulations, hit F3 to move LCD simulation to next audio section (series circuits)

### 1st audio card leading to Series Circuits section



### Last audio card of Series Circuit section



14. Have students address question in their journals (if you push GO ON on LCD simulation, the question will appear on screen)

**8. Is it possible to construct a series circuit with 4 devices where 3 of the devices work and 1 doesn't? Describe how current flows in the circuit to justify your answer.**

15. Have students voice their<sup>167</sup> opinion concerning whether or not it is possible to construct a series where 3 of 4 devices work. Ask the following:

- How does current move in the circuit?
- why or why not is it possible to construct such a circuit?

*(Get them to voice their opinion and explain how current moves. Some will just agree with what others have said. Challenge them by asking if that's what they really wrote down.)*

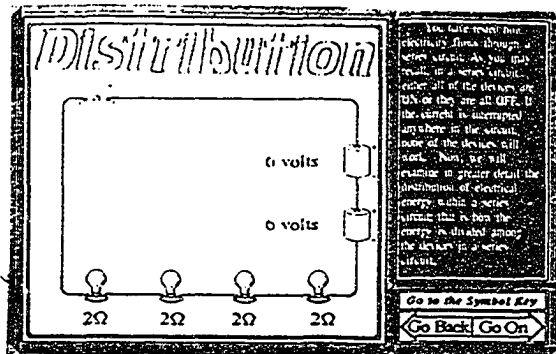
*Some students will say "I don't know" tell them they must have some idea because they use it everyday! Try and get them to form an opinion.*

### **YOUR TASK: GET THEM TO EXPLAIN & THEN CLARIFY WHAT THEY SAY BY REITERATING IT**

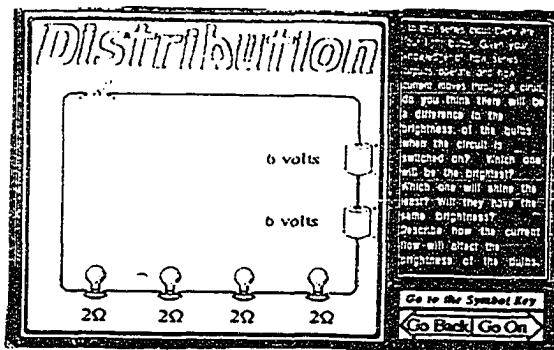
16. Students return to individual computers and hit **F3** to test their idea. (Students will go through simulation and instruction. At the end of series circuit section, the computer will stop them.)
17. When students start simulations, hit **F4** to move LCD simulation to next audio section (distribution of electricity within a circuit)
18. Have students discuss what they learned in the simulation. Ask the following:
- What did you learn?
  - According to the simulation, how can you construct a series circuit with 3 of 4 devices working?
  - How does current flow in the circuit to make it work or not work?
19. Have students answer journal questions at the bottom of series circuit page.
- What did they learn about series circuits?**
- How is what you learned different from what you originally thought?**

## 20. Start LCD simulation

### 1st audio card of Distribution section



### Last audio card of Distribution section



21. Have students address question in their journals (if you push GO ON on LCD simulation, the question will appear on screen)

**11. Will there be a difference in the brightness of the bulbs?**

22. Have students voice their opinion concerning a difference in the brightness of the bulbs. Ask the following:
- How does current move in the circuit?
  - why or why not is one bulb brighter than another?

*(Get them to voice their opinion and explain how current moves. Some will just agree with what others have said. Challenge them by asking if that's what they really wrote down.)*

*Some students will say "I don't know" tell them they must have some idea because they use it everyday! Try and get them to form an opinion.*

### **YOUR TASK: GET THEM TO EXPLAIN & THEN CLARIFY WHAT THEY SAY BY REITERATING IT**

23. Students return to individual computers and hit **F4** to test their idea. (Students will go through simulation and instruction. At the end of distribution section, the computer will stop them.)
24. When students start simulations, hit **F5** to move LCD simulation to next audio section (dead batteries)
25. Have students discuss what they learned in the simulation. Ask the following:
  - What did you learn?
  - According to the simulation, which bulb was the brightest?
  - How does current flow in the circuit to make them brighter?
26. Have students answer journal questions at the bottom of Distribution page.

**-What did they learn about the distribution of electrical energy?**

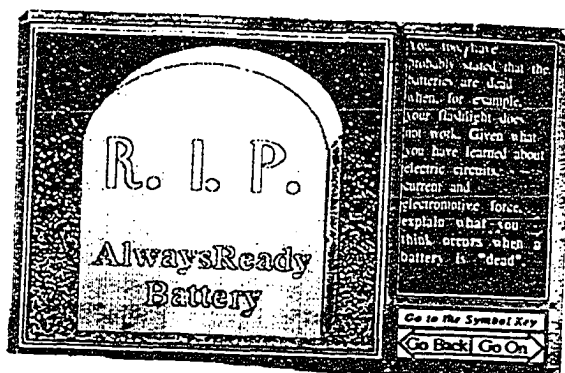
**-How is what you learned different from what you originally thought?**

27. Start LCD simulation 170

1st audio card of Dead Battery section



Last audio card of Dead battery section



28. Have students address question in their journals (if you push GO ON on LCD simulation, the question will appear on screen)

**17. What occurs when a battery is "dead"?**

29. Have students voice their opinion concerning a what occurs when a battery is dead. Ask the following:

- How does current move in the circuit?
- Why does a battery die?

(Get them to voice their <sup>171</sup>opinion and explain how current moves. Some will just agree with what others have said. Challenge them by asking if that's what they really wrote down.)

Some students will say "I don't know" tell them they must have some idea because they use it everyday! Try and get them to form an opinion.

### **YOUR TASK: GET THEM TO EXPLAIN & THEN CLARIFY WHAT THEY SAY BY REITERATING IT**

30. Students return to individual computers and hit F5 to test their idea. (Students will go through simulation and instruction. At the end of Dead battery section, the computer will stop them.)
31. There are no more audio sections.
32. Have students discuss what they learned in the simulation. Ask the following:
  - What did you learn?
  - According to the simulation, what occurs when a battery is "dead"?
  - How does current flow in the circuit to cause a battery to die?
33. Have students answer journal questions at the bottom of Dead Battery page.
  - What did they learn about what happens when a battery is "dead"?**
  - How is what you learned different from what you originally thought?**
34. Have the students click "OK" on their screens and go through the summary section.
35. As people finish, give them tests, ID cards, etc.

**\*\*\*\*MONITOR THE TIME- YOU SHOULD BEGIN DEAD BATTERY SECTION 40 MINUTES INTO COMPUTER TIME.**



E4: Computer Screens viewed in groups by CCCSWPIG treatment

**AMES**  
LABORATORY

Welcomes you to ...

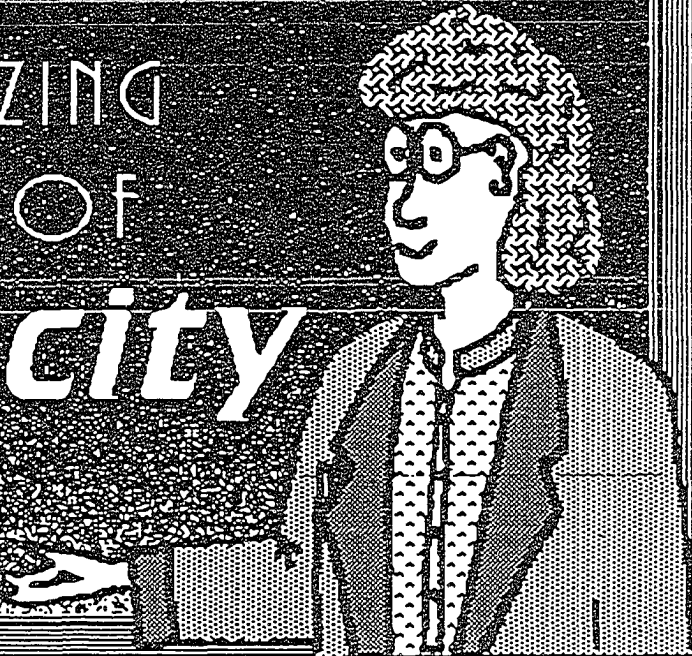
THE AMAZING  
WORLD OF  
*Electricit*

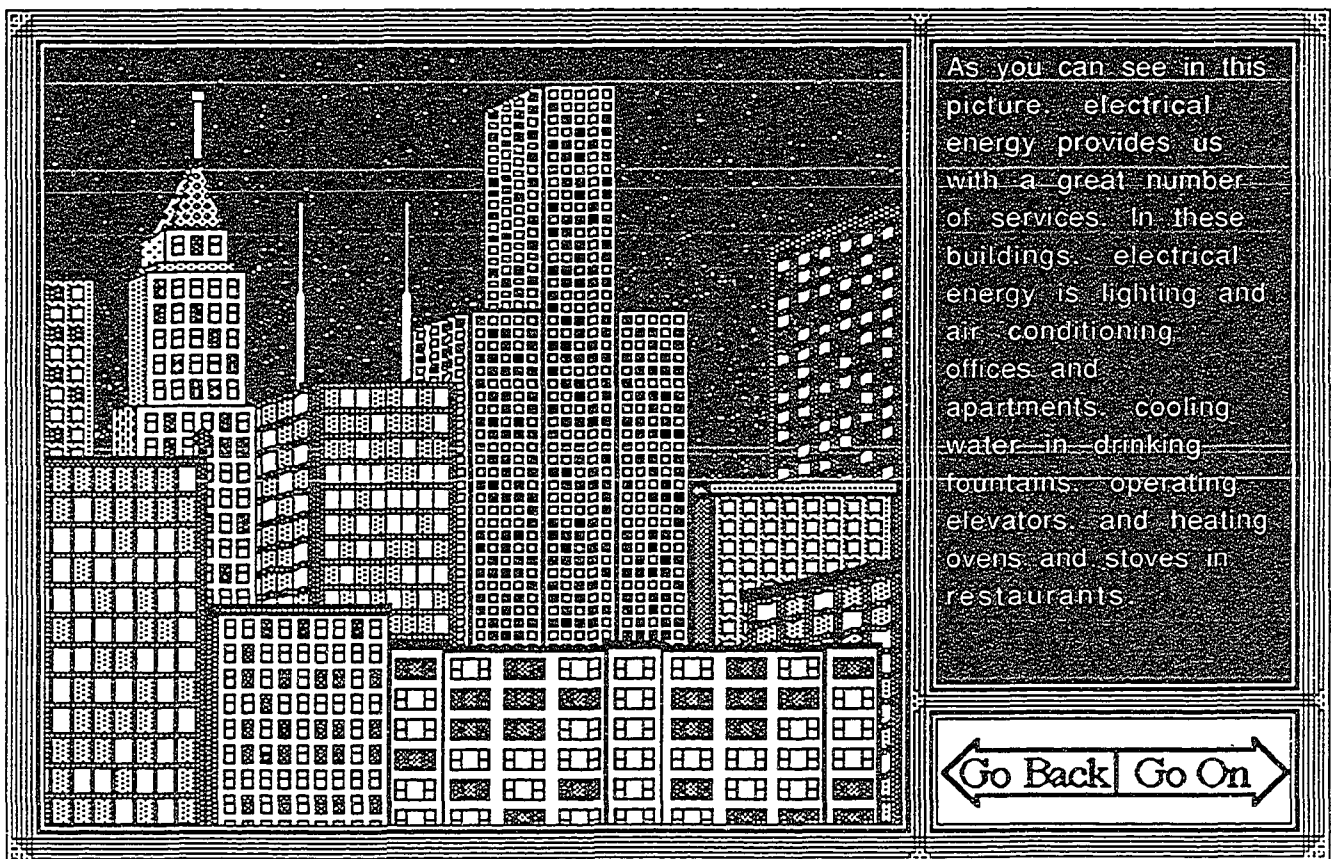
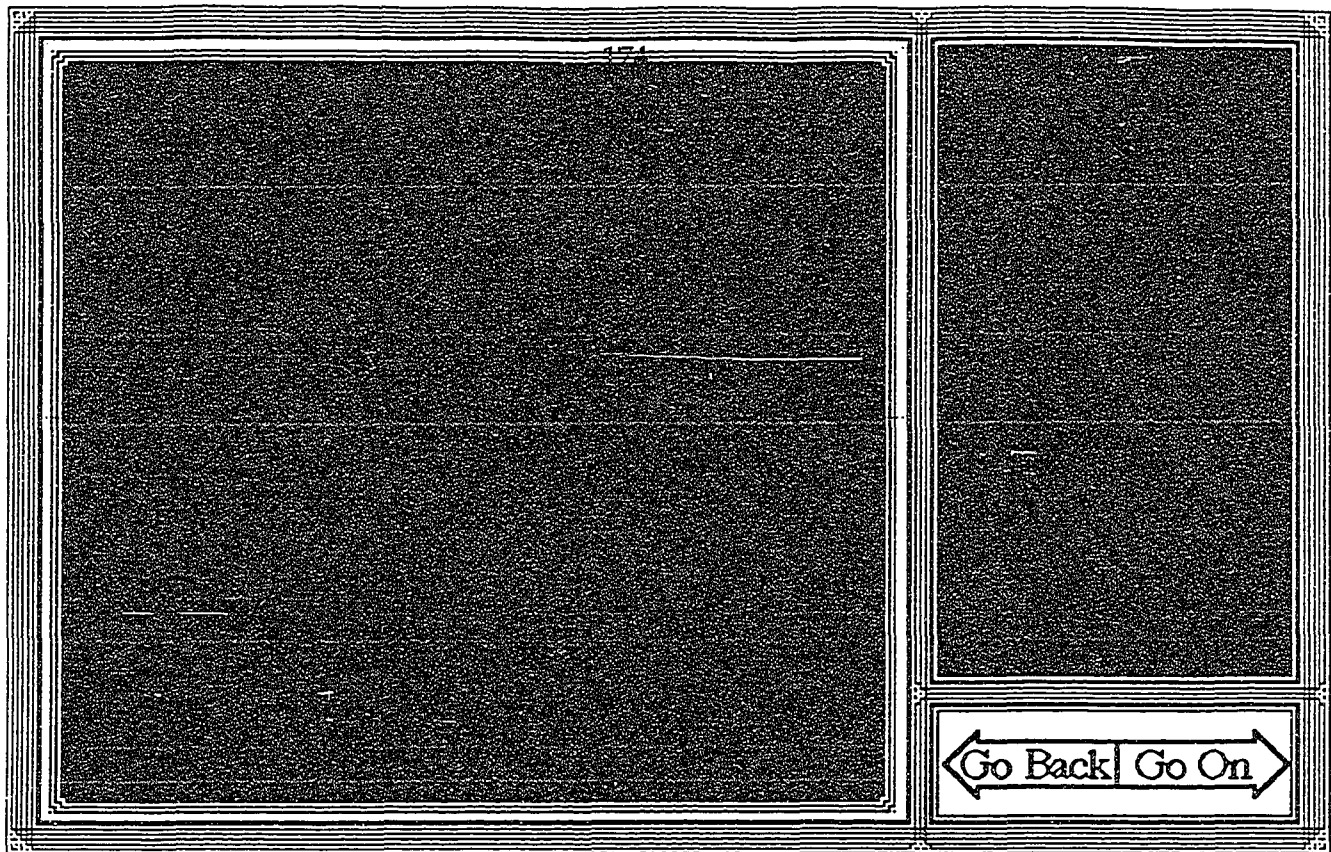


**AMES**  
LABORATORY

Welcomes you to ...

THE AMAZING  
WORLD OF  
*Electricity*







As you can see in this picture, electrical energy provides us with a great number of services. In these buildings, electrical energy is lighting and air conditioning offices and apartments, cooling water in drinking fountains, operating elevators, and heating ovens and stoves in restaurants.

◀ Go Back | Go On ▶



As you can see in this picture, electrical energy provides us with a great number of services. In these buildings, electrical energy is lighting and air conditioning offices and apartments, cooling water in drinking fountains, operating elevators, and heating ovens and stoves in restaurants.

◀ Go Back | Go On ▶





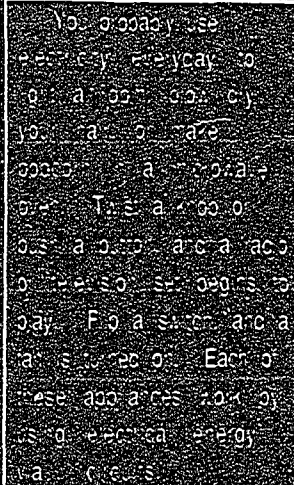
As you can see in this picture, electrical energy provides us with a great number of services. In these buildings, electrical energy is lighting and air conditioning offices and apartments, cooling water in drinking fountains, operating elevators, and heating ovens and stoves in restaurants.

Go Back Go On



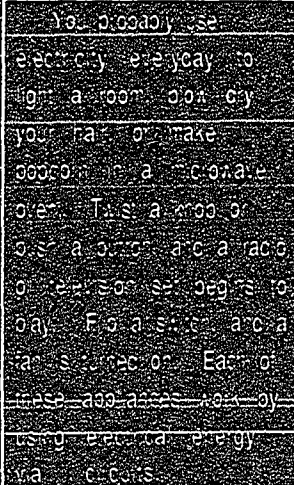
As you can see in this picture, electrical energy provides us with a great number of services. In these buildings, electrical energy is lighting and air conditioning offices and apartments, cooling water in drinking fountains, operating elevators, and heating ovens and stoves in restaurants.

Go Back Go On



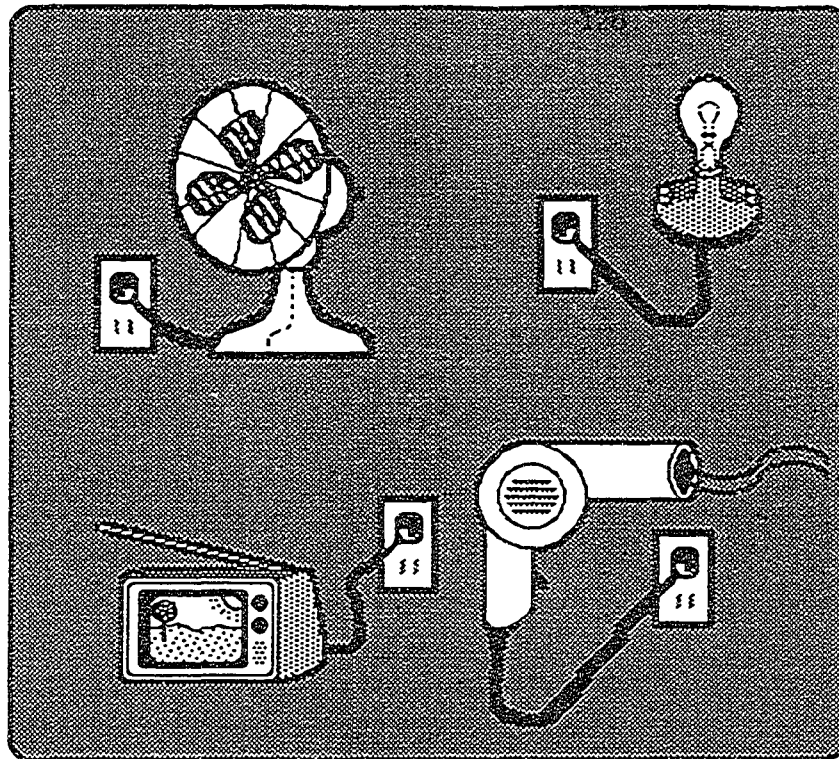
Do you know how electricity causes appliances to work?

Go Back | Go On



Do you know how  
electricity causes  
appliances to work?

Go Back | Go On



You probably use electricity every day to get a good night's sleep, to take a shower, to make a sandwich, to turn on a light, to play a video game, and a whole lot more. This is a good thing because electricity is a very useful energy source. For a station and a fan, it's the only way to get the job done. Each of these appliances work by using electrical energy to do their jobs.

Do you know how electricity causes appliances to work?

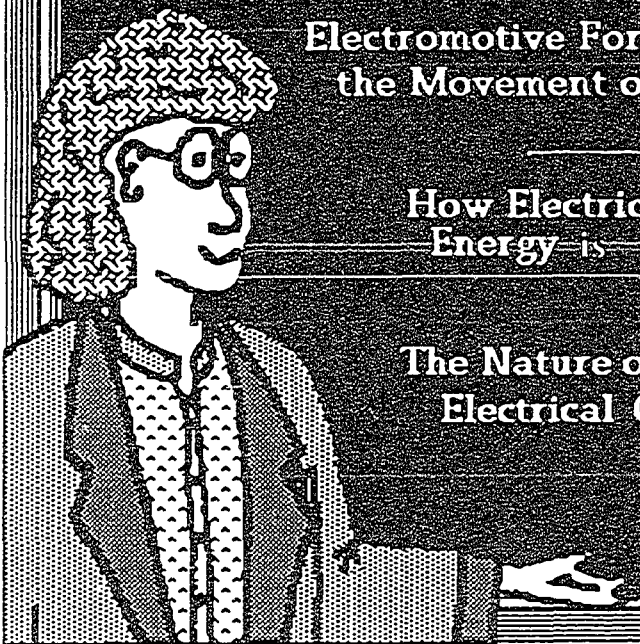
[Go Back](#) [Go On](#)

## Overview of Electrical Energy: Current & Circuits

Electromotive Force &  
the Movement of Electrons

How Electrical  
Energy is Transferred

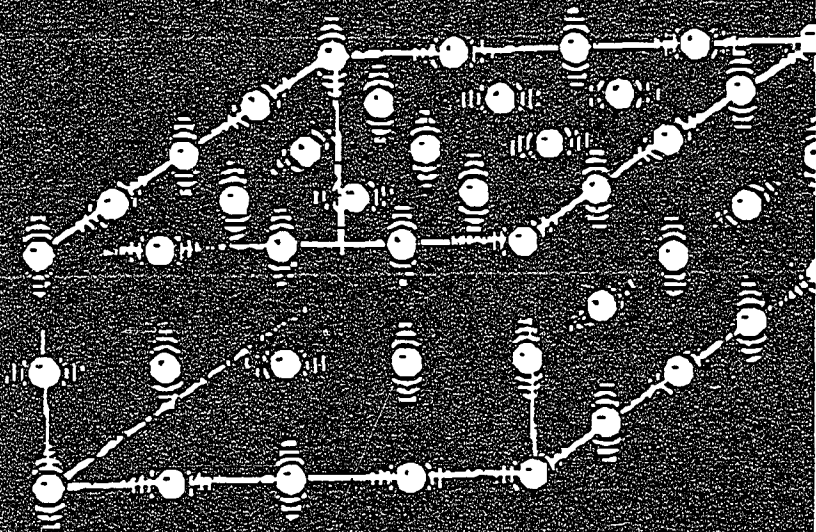
The Nature of  
Electrical Circuits



You will find out by studying the information in this stack where we will examine electrical energy, electric circuits, and measuring electrical parameters.

[Go Back](#) [Go On](#)

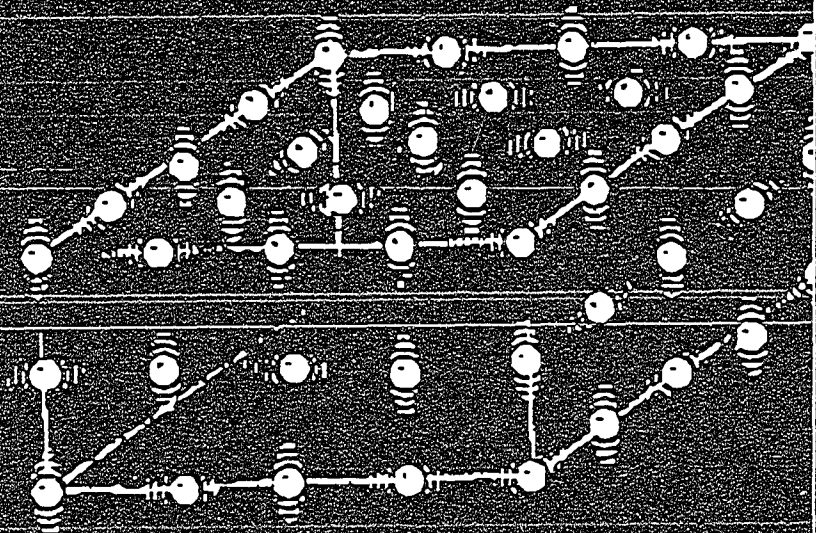




What is electrical energy?

To answer this question it is necessary to review some basic concepts about matter. As you may recall from previous science lessons, all matter is composed of atoms.

Go Back Go On



What is electrical energy?

To answer this question it is necessary to review some basic concepts about matter. As you may recall from previous science lessons, all matter is composed of atoms.

Go Back Go On





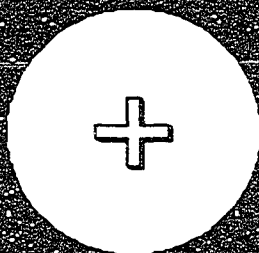
Proton



Neutron

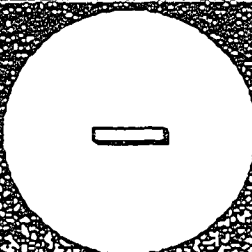
In turn, atoms are made up of subatomic particles which include protons, electrons, and neutrons. Protons and neutrons are found in the nucleus or center of an atom and account for most of the mass of an atom. Whirling around the nucleus are electrons.

Go Back Go On



*Proton*

*Electron*



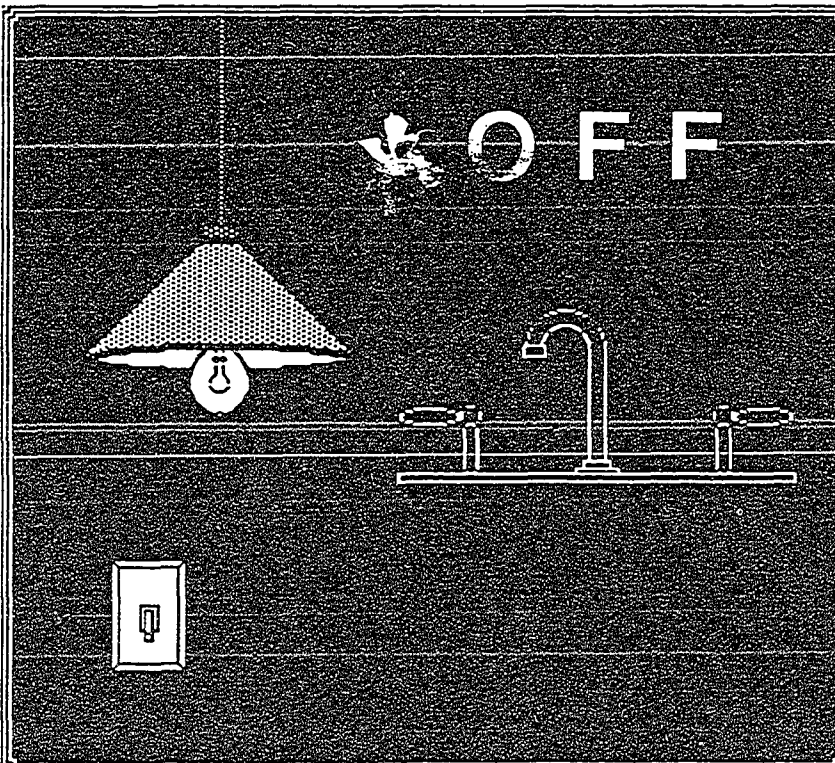
Protons and electrons possess electric charges. Protons are positively charged particles (+) and electrons are negatively charged particles (-).

Electrical energy arises from the interactions among these charged particles.

Go Back Go On

Particles with the same charges repel each other with increasing strength as they come closer together, and particles of different charges attract each other with increasing strength as they come closer together. This concept of how electrons and protons react to each other is the basis upon which electrical charges move to make electric appliances operate.

Go Back Go On



### Introduction to How Electrical Energy is Transferred:

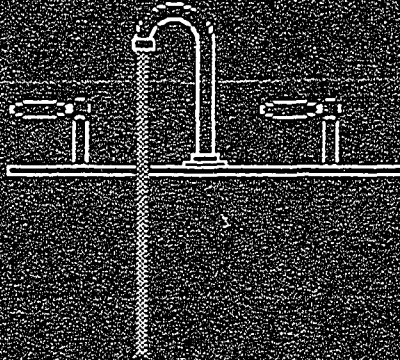
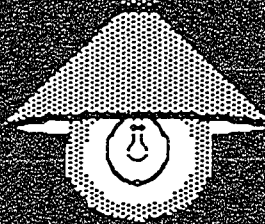
What do switching on a light and turning on a faucet have in common? Opening the faucet lets water flow through a pipe. Turning on an electric light switch permits

**electrons** to flow through the wires.

However, water will not flow through the pipe unless a **force** is present to move it.

Go Back Go On

ON

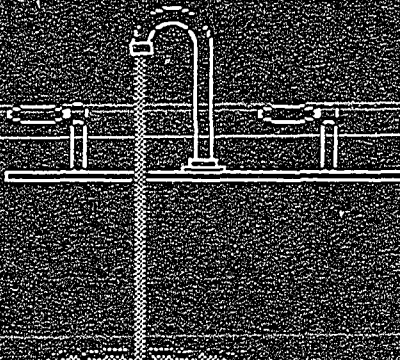
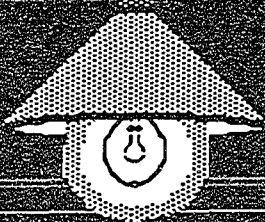


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Go Back Go On

ON

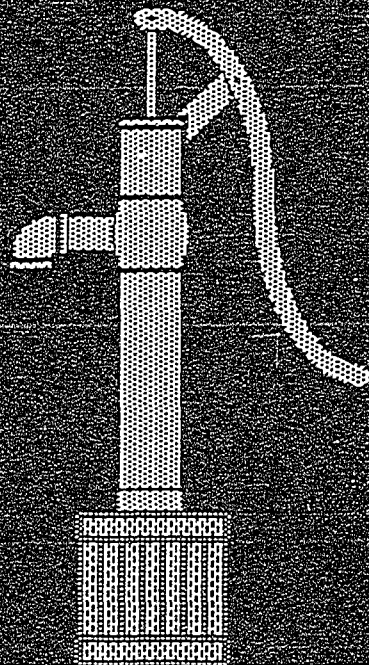


### Introduction to How Electrical Energy is Transferred:

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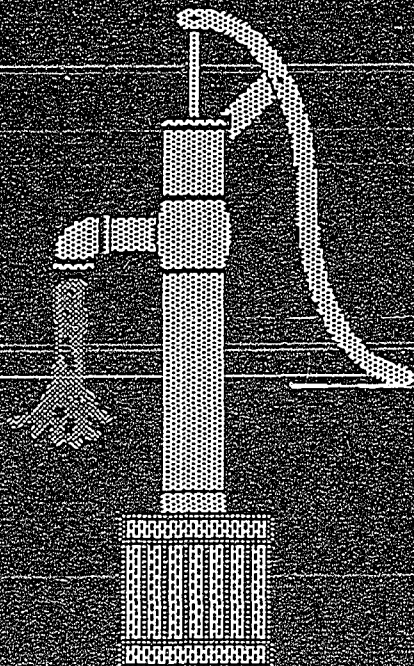
Go Back Go On





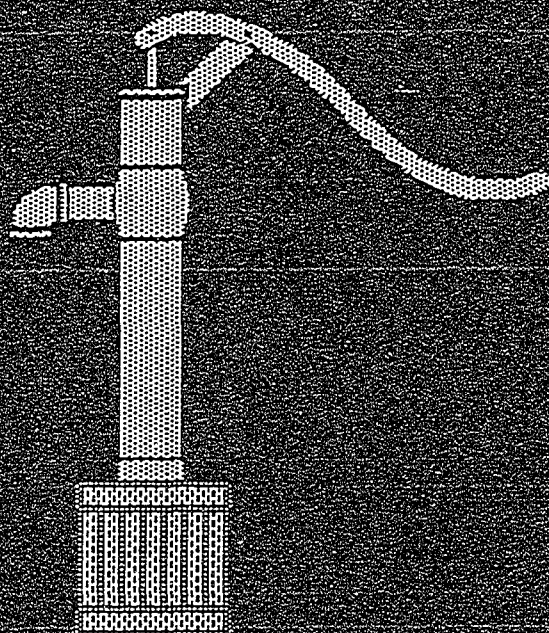
That force could be supplied by gravity causing the water to flow down hill, or a pump could supply the force needed to move the water. Similarly, electrons flowing through a conductor also need a force to cause them to move.

Go Back Go On



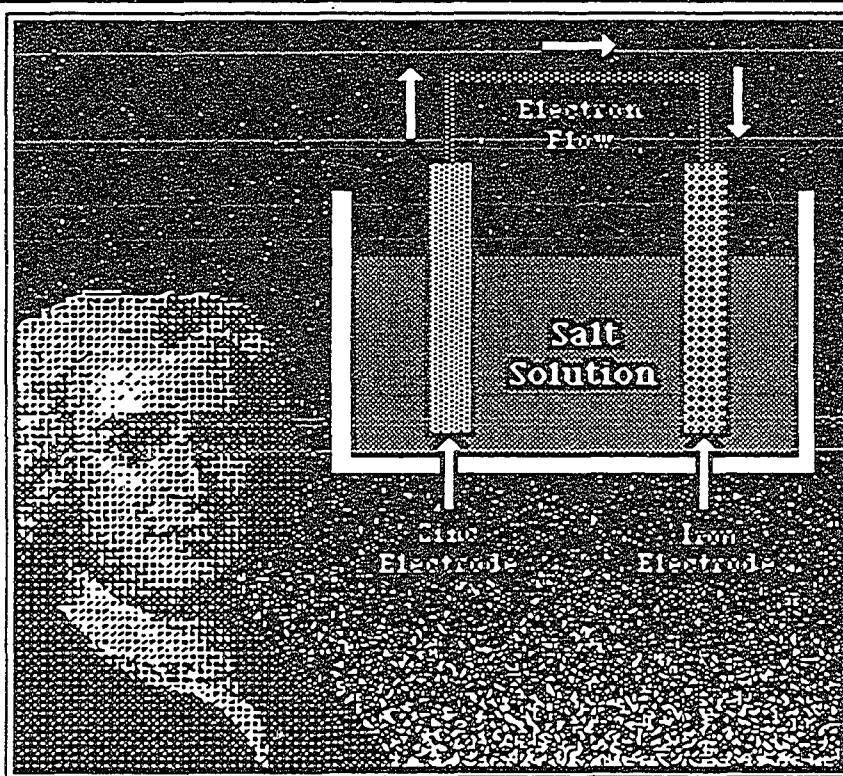
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Go Back Go On



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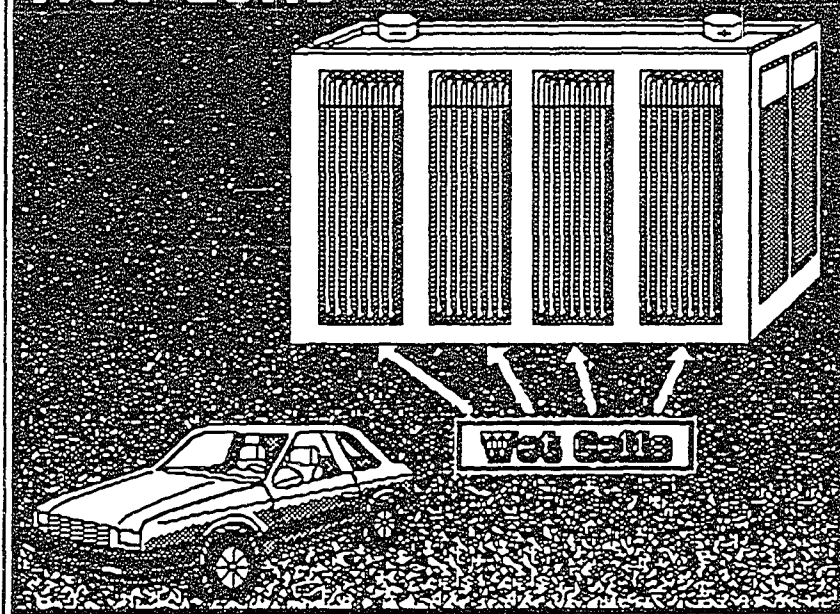
Go Back Go On



Around 1800, an Italian scientist named Alessandro Volta discovered a way to make **electrons** move through a **conductor**. Volta found that when the metals iron and zinc were placed with a salt water solution, a chemical reaction occurred; the chemical reaction between the metals and the salt solution caused the electrons to move. This arrangement of iron and zinc metals and salt solution is called an **electrochemical cell**.

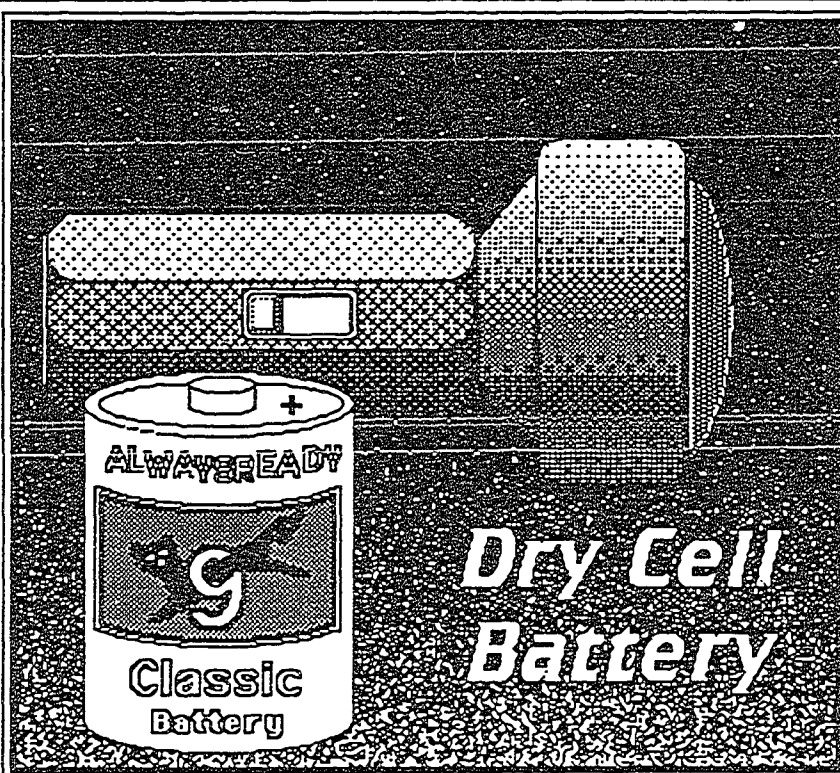
Go Back Go On

## ***Car Battery with Wet Cells***



An automobile battery is made up of several electrochemical cells. Inside of the battery an electrochemical cell stores energy that can cause electrons to move and thus create electrical energy.

Go Back Go On



An ordinary flashlight battery is also a kind of electrochemical cell. It is often called a dry cell because it does not contain a liquid form of the salt solution. Instead, a moist chemical mixture is used.

Go Back Go On





## Dry Cell Battery

An ordinary flashlight battery is also a kind of electrochemical cell. It is often called a dry cell because it does not contain a liquid form of the salt solution. Instead, a moist chemical mixture is used.

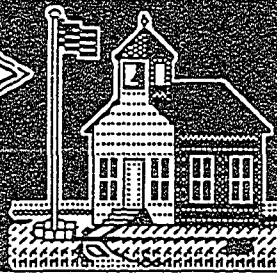
Go Back Go On



Energy Transfer Path



Streets & Avenues



In order for electrical devices to operate, electrical energy must be transferred from the battery to the device. Just like streets and avenues route people to specific locations within a city, an electric circuit transfers electrical energy (carried by electrical charges) to appliances. The rate at which electrons move through a circuit is called **current**.

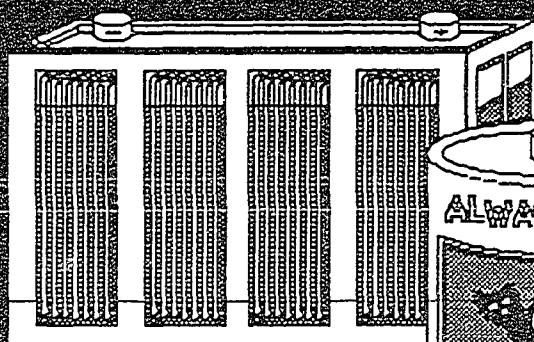
Go Back Go On



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Go Back Go On

## Power Source

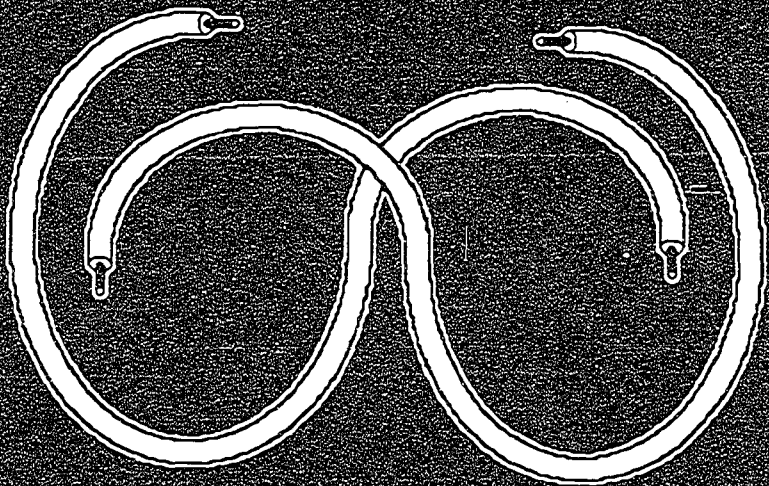


An electrical circuit is made of a power source and wires that can transfer the electrical energy stored in the power source. In addition, most circuits include a device or appliance which needs electrical energy to operate.

Go Back Go On



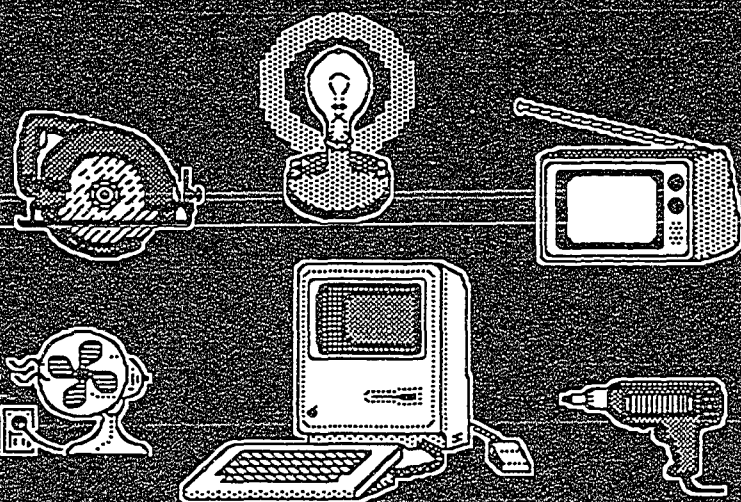
# Wires



An electrical circuit is made of a power source and wires that can transfer the electrical energy stored in the power source. In addition, most circuits include a device or appliance which needs electrical energy to operate.

Go Back Go On

# Appliances



An electrical circuit is made of a power source and wires that can transfer the electrical energy stored in the power source. In addition, most circuits include a device or appliance which needs electrical energy to operate.

Go Back Go On

## **Battery**

The battery may be moved around the screen by holding down the mouse button while moving the mouse.



## **Bulb**

The bulb may be moved around the screen by holding down the mouse button while moving the mouse.



Connect a Wire

## **Wires**

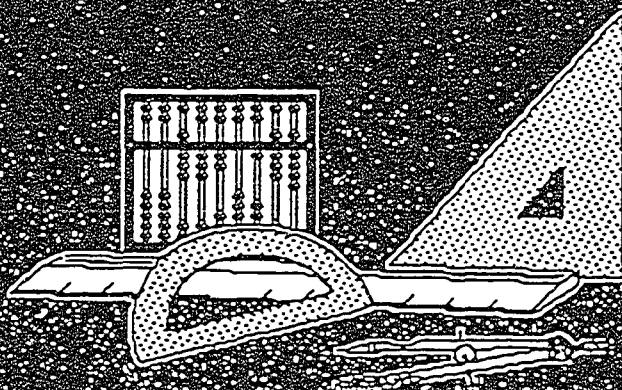
Click on this button to begin to connect both ends of the wires.

Describe how you think a circuit must be constructed and how electrical energy flows through the circuit to make the bulb light.

Shown here is a battery, bulb, and wires as well as instructions on how to use each item. After reading these instructions click the Go On button.

Go Back Go On

# Measuring



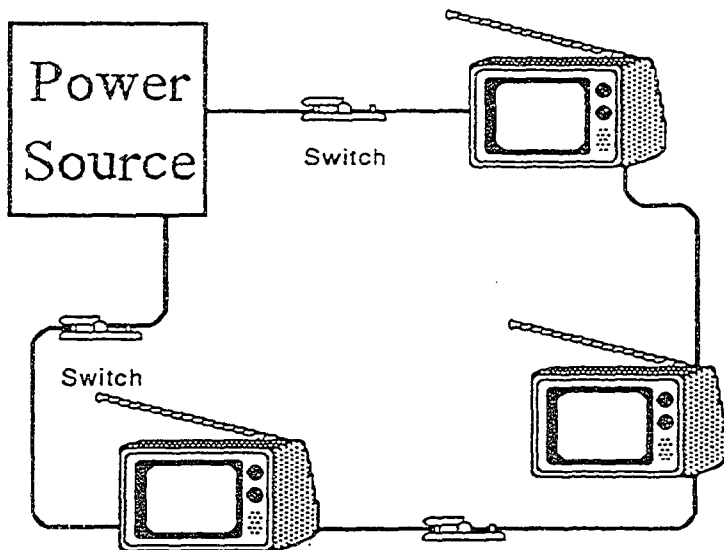
## Electrical Parameters

To this point, our discussion of electrical energy has been theoretical. That is, we have disclosed in principle how electrical energy is produced and how it is transferred to devices. More specifically, we have discussed what an electric circuit is, what current is, how electrical energy (in the form of electrons) moves within a circuit, the electromotive force that moves electrons, and how that force is produced.

In this section we want to discuss measuring electrical parameters.

[Go Back](#) [Go On](#)

# 191 Series Circuits

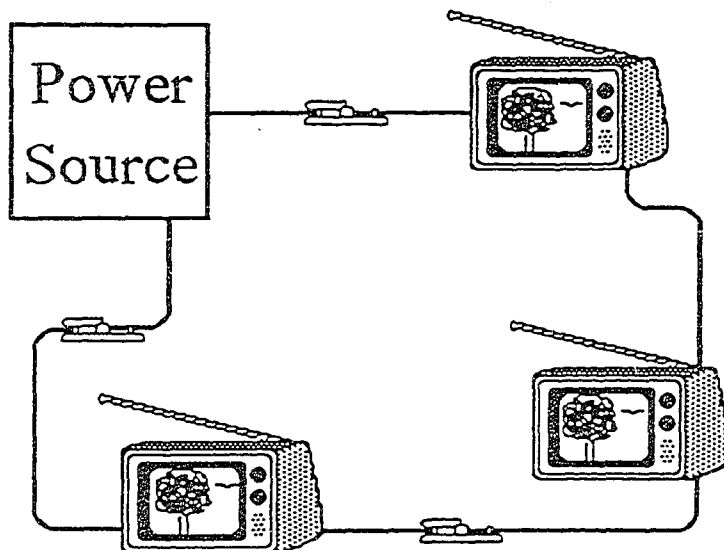


To this point, we have worked primarily with circuits that have included a single device or appliance. There are, however, circuits in which more than one device is connected to a power source. One method in which several devices can be connected in a circuit is called **series wiring**. In a series circuit the multiple devices are connected one after the other. In a **series circuit**, the same current must flow through each device in the circuit.

*Go to the Symbol Key*

*Go Back* *Go On*

# Series Circuits

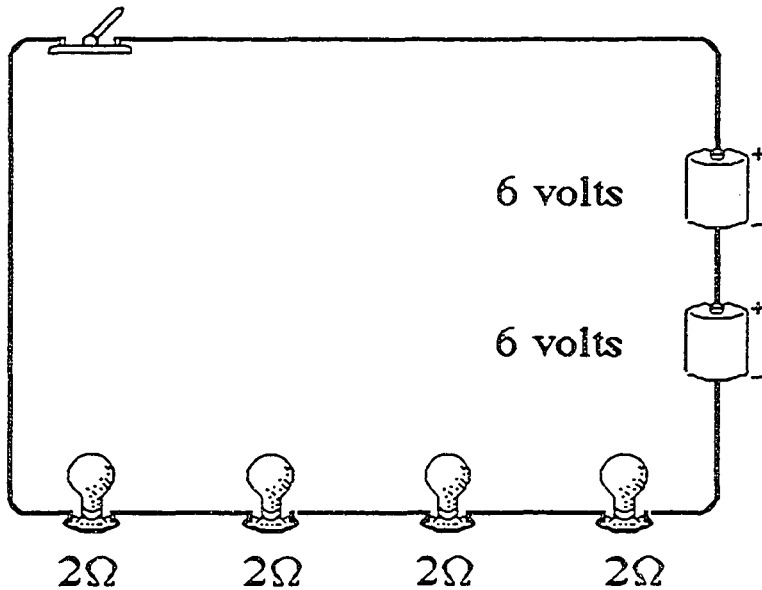


Given what you have learned about the way circuits operate and how current moves through a circuit, it is possible to construct a series circuit with 3 devices where 3 devices work & 1 does not. Many students know that it is possible to construct a series circuit with 4 devices in which 4 of the devices work & 1 does not. Do you think that these students are correct? Sketch the circuit that justifies your answer. Describe how the current flows.

*Go to the Symbol Key*

*Go Back* *Go On*

# Distribution<sup>192</sup>

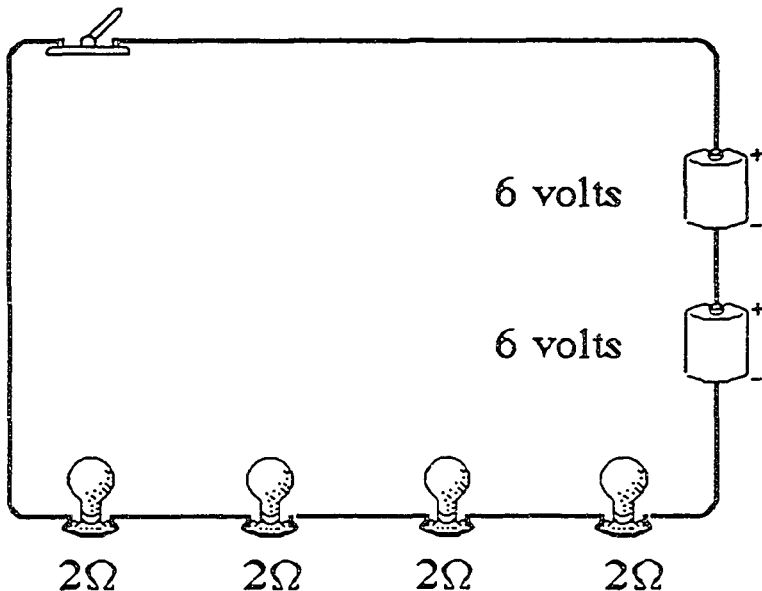


You have tested how electricity flows through a series circuit. As you may recall, in a series circuit, either all of the devices are ON or they are all OFF. If the current is interrupted anywhere in the circuit, none of the devices will work. Now, we will examine in greater detail the distribution of electrical energy within a series circuit, that is, how the energy is divided among the devices in a series circuit.

[Go to the Symbol Key](#)

[Go Back](#) [Go On](#)

# Distribution

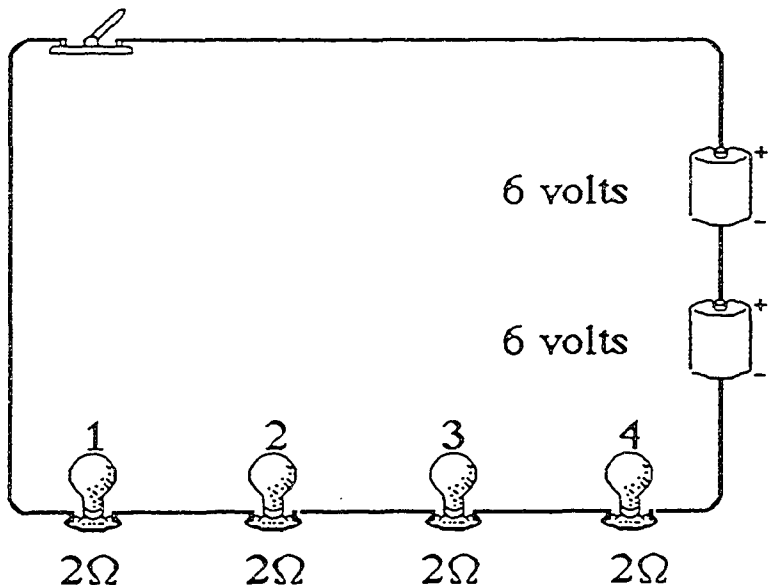


In this series circuit, there are four light bulbs. Given your knowledge of how series circuits operate and how current moves through a circuit, do you think there will be a difference in the brightness of the bulbs when the circuit is switched on? Which one will be the brightest? Which one will shine the least? Will they have the same brightness? Describe how the current flow will affect the brightness of the bulbs.

[Go to the Symbol Key](#)

[Go Back](#) [Go On](#)

# Distribution<sup>193</sup>



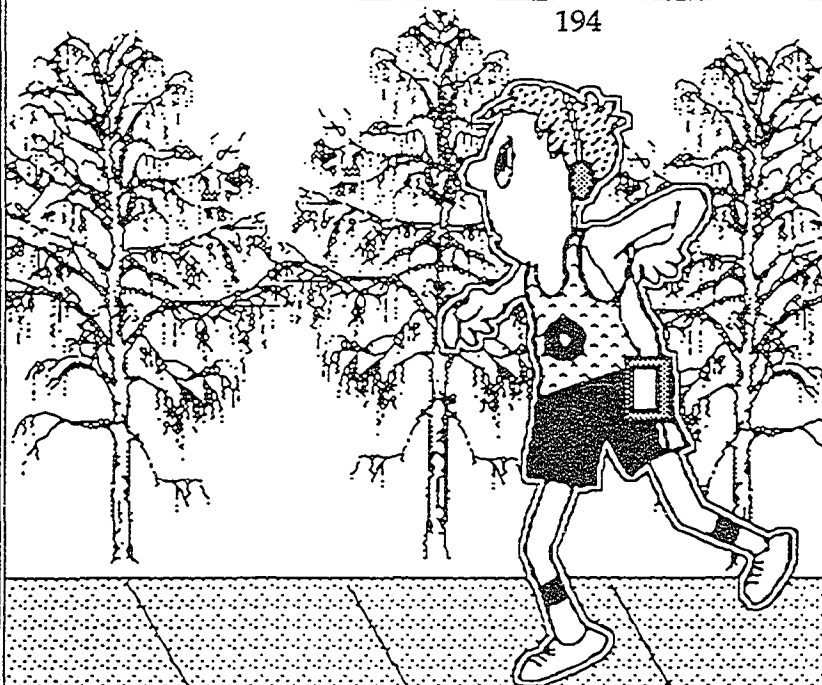
Before studying electricity, some students think that bulbs 3 and 4 will receive less electrical energy than bulbs 1 and 2. Others think that bulbs 1 and 2 receive less electrical energy than bulbs 3 and 4.

Do you think these students are correct? Explain why or why not.

*Go to the Symbol Key*

*Go Back* *Go On*





Trenton runs five miles every afternoon following his English course. He likes to run on the trails in the woods near his home. Typically, he runs alone with his walkman and listens to the radio or a Roxette cassette tape. Today, while Trenton was running, his walkman would not work because the batteries were dead. What does this mean?

*Go to the Symbol Key*

Go Back Go On

R. I. P.

Always Ready  
Battery

You, too, have probably stated that the batteries are dead when, for example, your flashlight does not work. Given what you have learned about electric circuits, current and electromotive force, explain what you think occurs when a battery is "dead".

*Go to the Symbol Key*

Go Back Go On

APPENDIX F. STUDENT JOURNALS USED WITH CCCSW AND  
CCCSWPIG TREATMENTS

- F1: CCCSW student journal
- F2: CCCSWPIG student journal

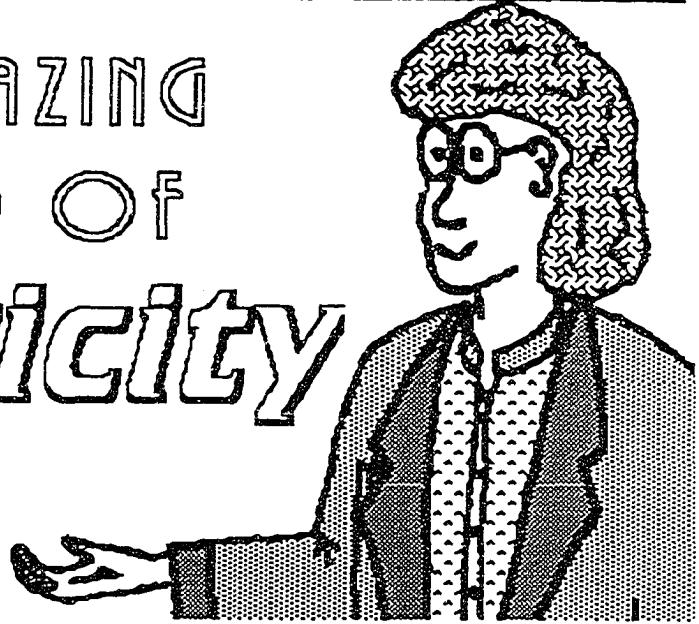


F1: CCCSW student journal



Welcomes you to ...

THE AMAZING  
WORLD OF  
*Electricity*



Student Journal

Two digit section #

\_\_\_\_\_

Last 4 digits of SS #

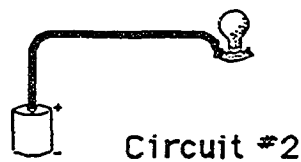
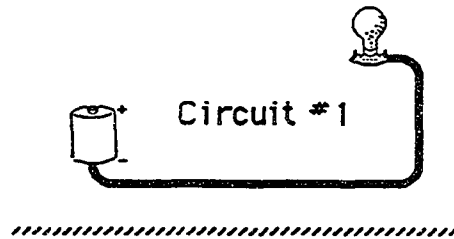
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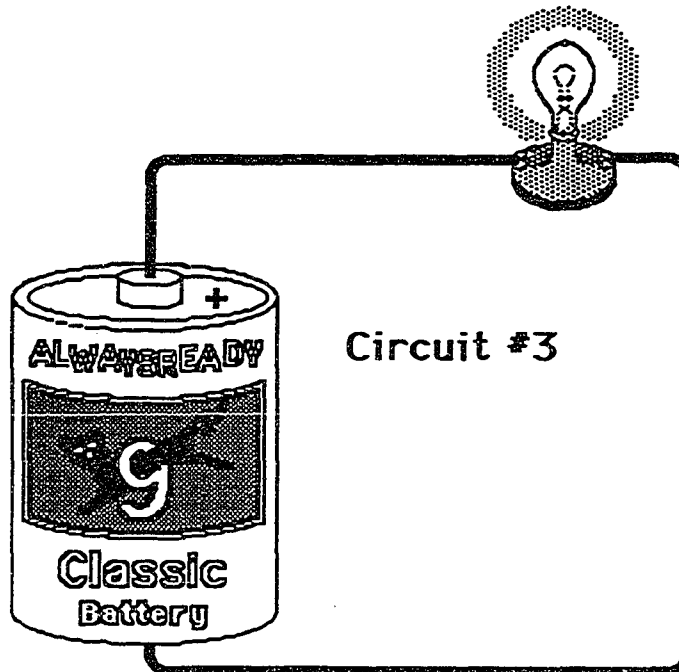
**1. Describe/sketch how you think a circuit must be constructed and explain how electrical energy flows through the circuit to make a bulb light.**

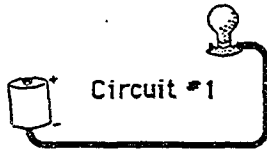
[illegible]

If your simulation circuit looks like circuit 1 or 2,  
**go to page 4.**



If your simulation circuit looks like circuit 3,  
**skip page 4 & go to page 5.**



Sink Theory

2a. Will circuit 1 cause the bulb to light? \_\_\_\_\_

2b. Describe how the electrical energy in circuit 1 flows to justify your answer.

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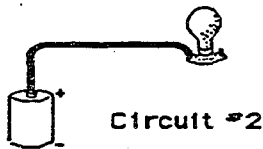
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3a. Will circuit 2 cause the bulb to light? \_\_\_\_\_

3b. Describe how the electrical energy in circuit 2 flows to justify your answer.

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3c. What is the difference between circuit 1 and 2?

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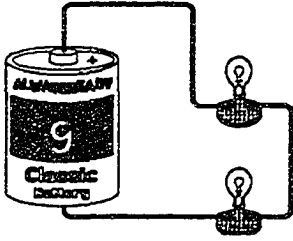
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Clashing Current Theory

In this circuit there are two light bulbs at different locations within the circuit.

4a. Will the circuit cause the both bulbs to light? \_\_\_\_\_

4b. Describe how the electrical energy in the circuit flows to justify your answer.

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5. What happened when the circuit in the simulation was tested?

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Measuring Electrical Parameters

Ohms' Law       $I = \frac{V}{R}$

Car battery = 12 volts

The resistance for the parking lights is 3 ohms.

**6.** When the parking lights are on, how much current is required?

The radio in this same car requires a current of 6 amperes.

**7a.** What is the resistance of the radio?

One evening while waiting in the car for a friend, you decide to play the radio and keep the headlights on.

**7b.** Given the information above, calculate the resistance and the current needed to operate both the headlights and the radio when series wired.

**7c.** Given the information above, what is the difference in current needed to operate the parking lights and radio as compared to the headlights and radio?

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Series Circuits

**8a.** Given what you have learned about the way circuits operate and how current moves through a circuit, is it possible to construct a series circuit with four televisions where three televisions work and one does not?

\_\_\_\_\_

**8b.** Many students think that it is possible to construct a series circuit with four televisions in which three of the televisions work and one does not. Do you think that these students are correct? \_\_\_\_\_

**8c.** Describe/sketch the circuit that justifies your answer. Describe how the current flows within your circuit.

\_\_\_\_\_

\_\_\_\_\_

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\_\_\_\_\_

**9.** Describe what happens to the televisions when all of the switches are in the ON position.

\_\_\_\_\_

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**10a.** Describe what happens to the televisions when one of the switches is moved to the OFF position.

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**10b.** moved to the OFF position and how current flows through the circuit.

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Distribution of Electrical Energy in Series Circuits

**11a.** Given your knowledge of how series circuits operate and how current moves through a circuit, do you think that there will be a difference in the brightness of the bulbs when the circuit is switched on? \_\_\_\_\_

**11b.** Which bulb will be the brightest? \_\_\_\_\_

**11c.** Which one will shine the least? \_\_\_\_\_

**11d.** Will they have the same brightness? \_\_\_\_\_

**11e.** Describe how you think the current flow will affect the brightness of the bulbs.

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**12.** Are the students who believe bulbs 1 and 2 or bulbs 3 and 4 will vary in brightness correct? Explain why or why not.

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Distribution of Electrical Energy in Series Circuits cont.

**13.** Given the resistance of each bulb and the voltage of the batteries, calculate the amount of current needed for each bulb. (Remember,  $I = V/R$ .)

**14.** Is there a difference in the brightness of the four bulbs? \_\_\_\_\_

**15.** Record the 5 ammeter readings for the current throughout the circuit.

1.                      2.                      3.                      4.                      5.

**16a.** Calculate the current needed for the entire circuit.  
(Remember,  $R = R_1 + R_2 + R_3 + R_4$ ;  $I = V/R$ )

**16b.** What is the difference between the current calculated for each individual bulb and all four bulbs together? \_\_\_\_\_

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Dead Battery

**17.** Given what you have learned about electric circuits, current, and electromotive force, explain what you think occurs when a battery is "dead".

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**18a.** Which device (toaster, fan, and light bulb) do you think will consume the greatest amount of electromotive force and why?

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**18b.** Record the readings from each voltmeter.

1.                      2.                      3.

**19.** Remembering that current flows from negative to positive, what does the sequence of voltmeter readings tell you about the electromotive force?

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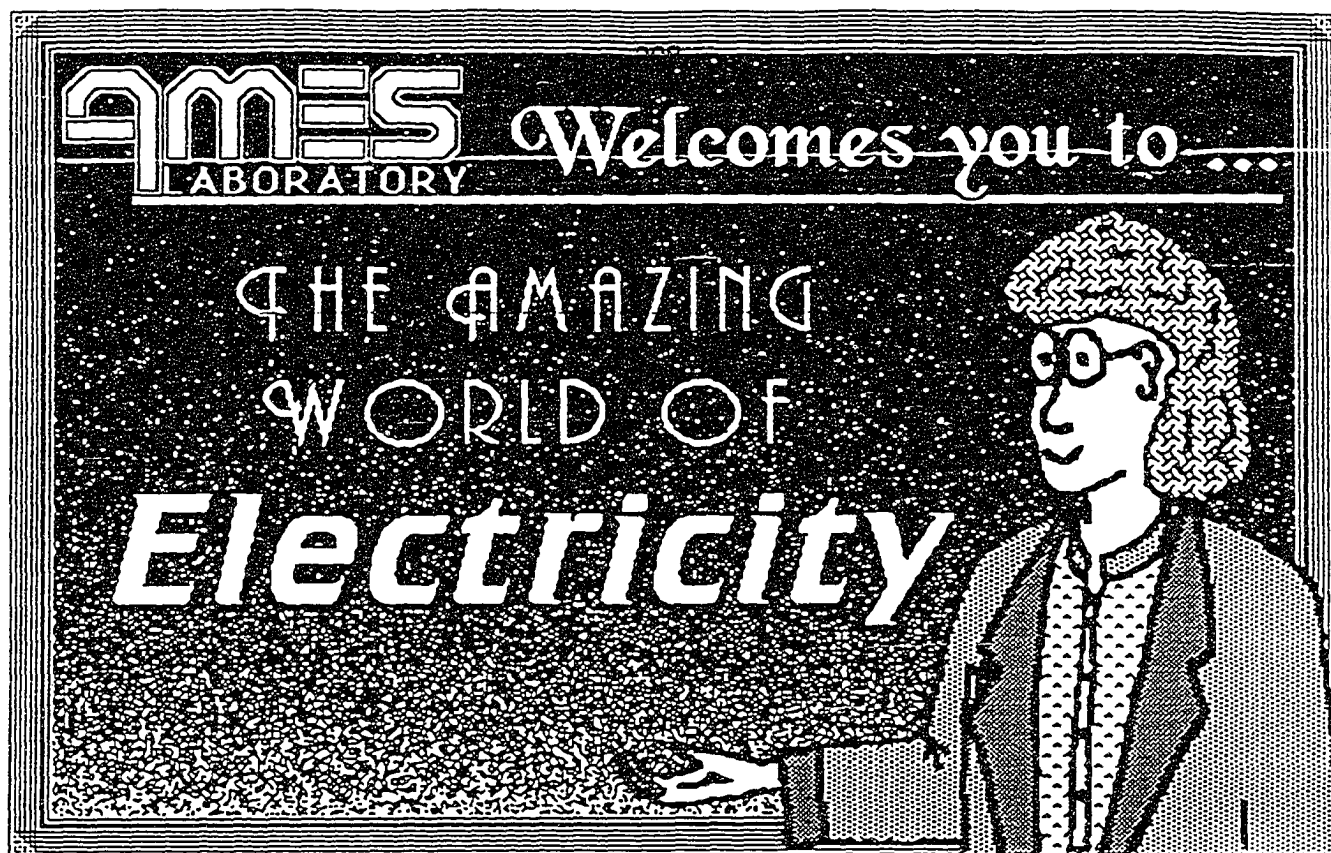
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F2: CCCSWPIG student journal



## Student Journal

Two digit section #

\_\_\_\_\_

Last 4 digits of SS #

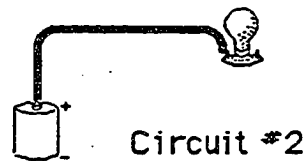
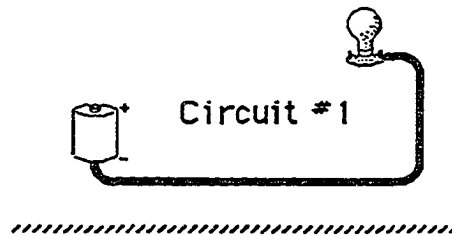
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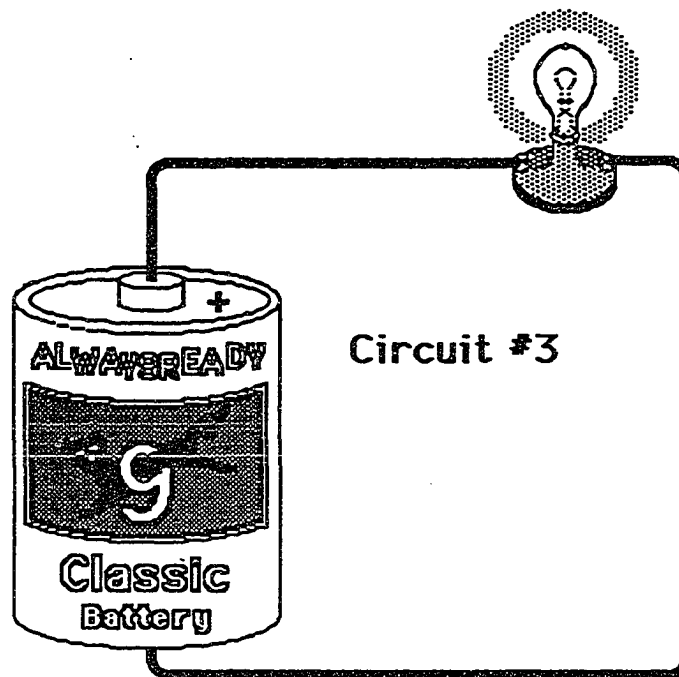
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[illegible]

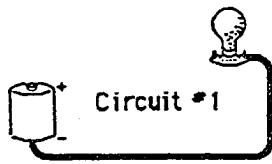
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Sink Theory

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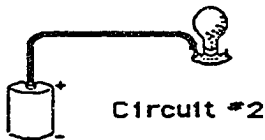
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**3a.** Will circuit 2 cause the bulb to light? \_\_\_\_\_

**3b.** Describe how the electrical energy in circuit 2 flows to justify your answer.

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**3c.** What is the difference between circuit 1 and 2?

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What did you learn about how a circuit is constructed and how electricity flows in a circuit?

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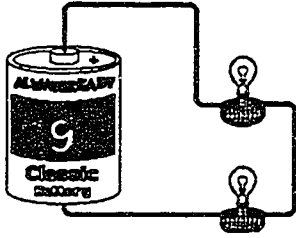
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How is this different from what you previously thought about circuits?

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Clashing Current Theory

In this circuit there are two light bulbs at different locations within the circuit.

**4a.** Will the circuit cause the both bulbs to light? \_\_\_\_\_

**4b.** Describe how the electrical energy in the circuit flows to justify your answer.

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**5.** What happened when the circuit in the simulation was tested?

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What did you learn about how a circuit is constructed and how electricity flows in a circuit?

---



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How is this different from what you previously thought about circuits?

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Series Circuits

**8a.** Given what you have learned about the way circuits operate and how current moves through a circuit, is it possible to construct a series circuit with four televisions where three televisions work and one does not?

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**8b.** Many students think that it is possible to construct a series circuit with four televisions in which three of the televisions work and one does not. Do you think that these students are correct? 

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**8c.** Describe/sketch the circuit that justifies your answer. Describe how the current flows within your circuit.

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**9.** Describe what happens to the televisions when all of the switches are in the ON position.

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Series Circuits cont.

**10a.** Describe what happens to the televisions when one of the switches is moved to the OFF position.

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**10b.** Describe what occurred physically in the circuit when one of the switches is moved to the OFF position and how current flows through the circuit.

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What did you learn about series circuits?

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How is this different from what you previously thought?

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Distribution of Electrical Energy in Series Circuits

**11a.** Given your knowledge of how series circuits operate and how current moves through a circuit, do you think that there will be a difference in the brightness of the bulbs when the circuit is switched on? \_\_\_\_\_

**11b.** Which bulb will be the brightest? \_\_\_\_\_

**11c.** Which one will shine the least? \_\_\_\_\_

**11d.** Will they have the same brightness? \_\_\_\_\_

**11e.** Describe how you think the current flow will affect the brightness of the bulbs.

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**12.** Are the students who believe bulbs 1 and 2 or bulbs 3 and 4 will vary in brightness correct? Explain why or why not.

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Distribution of Electrical Energy in Series Circuits cont.

**13.** Given the resistance of each bulb and the voltage of the batteries, calculate the amount of current needed for each bulb. (Remember,  $I = V/R$ .)

**14.** Is there a difference in the brightness of the four bulbs? \_\_\_\_\_

**15.** Record the 5 ammeter readings for the current throughout the circuit.

1.                      2.                      3.                      4.                      5.

**16a.** Calculate the current needed for the entire circuit.  
(Remember,  $R = R_1 + R_2 + R_3 + R_4$ ;  $I = V/R$ )

**16b.** What is the difference between the current calculated for each individual bulb and all four bulbs together? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

What did you learn about dispersion of electricity within a series circuit?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

How is this different from what you previously thought about dispersion of electricity within a series circuit?

\_\_\_\_\_

\_\_\_\_\_

Dead Battery

**17.** Given what you have learned about electric circuits, current, and electromotive force, explain what you think occurs when a battery is "dead".

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**18a.** Which device (toaster, fan, and light bulb) do you think will consume the greatest amount of electromotive force and why?

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**18b.** Record the readings from each voltmeter.

1.                      2.                      3.

**19.** Remembering that current flows from negative to positive, what does the sequence of voltmeter readings tell you about the electromotive force?

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What did you learn about dead batteries?

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How is this different from what you previously thought about dead batteries?

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**APPENDIX G.     STUDENT ASSIGNMENT AND PARTICIPANT  
CONSENT LETTER**

Secondary/Elementary Education 301  
Media For Teachers

**\*\*\*Due Week #5      September 21-25**

Computer-based Instructional Activity Assignment

Week 4 you will participate in a computer-based instructional activity on electricity. The lesson is an example of how computer technology can be used in education.

Please discuss in 3-5 paragraphs how this kind of lesson could be integrated into a classroom. Specifically, describe a specific educational situation (include grade level, subject area, number of students in the class, ratio of students to teachers, and the kinds of students, i.e. gender, racial background, socioeconomic levels, etc.) and discuss how you would use this type of computer application in the classroom.

You may want to include in your discussion various features of a computer-based instructional application that may be important to your situation. These may include animation, graphics, sound, or the ability to simulate real-world experiences.

August 16, 1992

Dear 301 Student:

As you prepare for a career in education, there are many factors that may influence your ability to teach. The knowledge and experience students bring to your classroom may profoundly affect your ability, as a teacher, to communicate new information to them, and their ability to learn the information.

I am conducting a study to investigate how instruction can be designed to overcome students' preconceptions of science concepts. Specifically, the purpose of my study is to examine the use of a conceptual change approach about electricity with computer simulations, reflective journals, and peer group interactions.

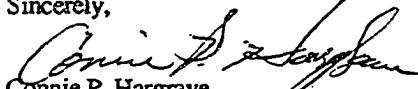
As part of your Secondary/Elementary Education 301 course, you will be required to participate in a computer-based science lesson on electricity. The purpose of the lesson is to provide you with instruction on how simple electric circuits operate. Following the computer-based lesson, you will be asked to complete assessment instruments over what you have learned. The results of the assessment instruments will in no way influence your grade in Secondary/Elementary Education 301.


In addition to participating in the computer-based science lesson, you will be required to write a review of the instructional implications of the lesson. Your review of the lesson will be factored into your course grade. Specific details for the review will be provided in class.

The data generated from the assessment instruments will be used to determine the effectiveness of the science lesson and will be examined only in a group context; your responses will be kept confidential and will not be reported on an individual basis.

Along with the assessment instruments, your scores on the American College Tests (ACT) are also needed for data analysis purposes. Although for this course you are required to participate in the computer-based lesson, it is your option to make these data available for use in this study. Please complete and sign the consent form below. If you do not want your data (from the assessment instruments and ACT scores) to be used in this study, please check the appropriate box.

Sincerely,

  
Connie P. Hargrave  
Doctoral Student  
Curriculum and Instructional Technology  
Iowa State University

  
Michael R. Simonson  
Professor, College of Education  
Iowa State University

I, \_\_\_\_\_, (\_\_\_\_\_, \_\_\_\_\_),  
(full name) social security no.

hereby consent to the use of the data I generate in the study described above. I also consent to the release of my ACT scores for this study. These data may be used exclusively for the study's data analysis purposes.

☐

I DO NOT want the data I generate to be used in this study.

**APPENDIX H. FACILITATOR TRAINING MATERIALS**

- H1: Overview of Facilitator Training and Preparation Procedures**
- H2: Materials for Facilitator Training Session 1**
- H3: Materials for Facilitator Training Session 2**

**H1: Overview of Facilitator Training and Preparation Procedures**

### **Overview of Facilitator Training and Preparation Procedures**

Five weeks prior to the implementation of the study, individuals to serve as facilitators for each treatment session were recruited and trained. A total of nine individuals volunteered to facilitate the treatment sessions for the study. All of the facilitators had previously taught or were currently teaching Instructional Media. Five graduate teaching assistants, who at the time of the study were teaching sections of Instructional Media, served as facilitators for the study. In addition, two professors, one university instructor, and one computer science graduate research assistant served as facilitators for the treatment of the study.

Three days before the beginning of the 1992 Fall semester, the researcher made a brief presentation to the instructors of the Instructional Media course. The purpose of the presentation was to introduce the conceptual framework of the study to the instructors who would integrate the study's activities into each section of the course and facilitate various treatment sessions. Specifically, the presentation included a discussion of the problem to be investigated, the hypothesis, the treatment groups, and the activities of each treatment. In addition, logistical considerations for implementing the study and issues related to integrating the study's activities into the Instructional Media course were discussed.

Two training sessions were held for the individuals who would facilitate the treatment sessions. Conducted by the researcher, the purpose of the training sessions was to familiarize the facilitators with the computer simulation and the procedures to be used for the study.

The first training session was held four weeks prior to the implementation of the treatment. Each facilitator received a packet of training materials that included: facilitator instructions, a treatment

information sheet, directions to be read aloud for each treatment, directions on operating a mouse, a student journal, the computer-based instructional activity assignment, and directions for troubleshooting the computer simulation. In addition to discussing the contents of the training packet, the following topics were discussed at the first training session: schedule of events for the study; facilitators' schedules, purpose and hypotheses of study, events of each treatment, logistical considerations for the study (i.e. room arrangements and the room rotation schedule), and guidelines for grading the student assignment based on the study. Last, each facilitator went through the computer program to become familiar with the content, the organization of the paths, and the various features of the Hypercard stack.

The second training session for the facilitators was conducted by the researcher three days before the implementation of the treatment was to begin. The purpose of the second training session was to review the procedures to be used for the implementation of the study and to make the facilitators aware of potential difficulties that could arise. Each facilitator received a packet of training materials that included: facilitator instructions, directions to be read aloud for each treatment, directions for troubleshooting the computer simulation, and the official facilitator schedule.

In addition to discussing the contents of the training packet, the following topics were discussed in detail at the second training session: events of each treatment, logistical considerations for the study (i.e. facilitator packets, test packets, and room arrangements), and the results of the pilot study. In addition to the packet of training materials, each facilitator received a concept map of the computer program. The concept map outlined the organization of the presentation and simulation paths and listed key codes (function keys) for moving around the program should a problem arise. The

researcher reviewed in detail the organizational structure of the computer program and the use of function keys to re-orient a student who may get into the wrong section of the program.

To maintain the consistency of the treatment, the same individual facilitated all of the conceptual change computer simulation, writing, and peer group interaction treatment sessions. One week before the study began, two training sessions were conducted for the individual who would facilitate the conceptual change computer simulation, writing, and peer group interaction treatment. The training sessions focused on the ideational confrontation steps and procedures to be used for the group discussions. Particular attention was given to familiarizing the individual with the organization of the facilitator's version of the computer program and the simulation path of the computer program to be used by the students.



**H2: Materials for Facilitator Training Session 1**

# **The Amazing World of Electricity**

**Facilitator Training Session**

August, 1992

## Schedule for Facilitators

Day	Time	Facilitator	Treatment	Room
Monday	10-12	Connie Hargrave	CP	Micro
Monday	10-12	Terry Corwin	CCCS	TV
Monday	10-12	_____	CCCSW	301
Monday	10-12	Karen Jurasek	CCCSWPIG	N055
Monday	12-2	Terry Corwin	CP	N055
Monday	12-2	Dawn Poole	CCCS	Micro
Monday	12-2	_____	CCCSW	TV
Monday	12-2	Karen Jurasek	CCCSWPIG	301
Monday	2-4	XXXXXXXXXXDr. Volker's SectionXXXXXXXXXXXXXXX		
Tuesday	10-12	Jody Rude	CP	TV
Tuesday	10-12	Yuh-soon Park	CCCS	301
Tuesday	10-12	_____	CCCSW	N055
Tuesday	10-12	Karen Jurasek	CCCSWPIG	Micro
Tuesday	12-2	Dawn Poole	CP	Micro
Tuesday	12-2	Terry Corwin	CCCS	TV
Tuesday	12-2	_____	CCCSW	301
Tuesday	12-2	Karen Jurasek	CCCSWPIG	N055
Tuesday	2-4	Jody Rude	CP	N055
Tuesday	2-4	Yuh-soon Park	CCCS	Micro
Tuesday	2-4	_____	CCCSW	TV
Tuesday	2-4	Karen Jurasek	CCCSWPIG	301
Wednesday	12-2	Jody Rude	CP	301
Wednesday	12-2	Denise Schmidt	CCCS	N055
Wednesday	12-2	_____	CCCSW	Micro
Wednesday	12-2	Karen Jurasek	CCCSWPIG	TV
Thursday	8-10	Jody Rude	CP	TV
Thursday	8-10	Denise Schmidt	CCCS	301
Thursday	8-10	_____	CCCSW	N055
Thursday	8-10	Karen Jurasek	CCCSWPIG	Micro

<u>Day</u>	<u>Time</u>	<u>Facilitator</u>	<u>Treatment</u>	<u>Room</u>
Thursday	10-12	Kayt Sanwood	CP	Micro
Thursday	10-12	Terry Corwin	CCCS	TV
Thursday	10-12	_____	CCCSW	301
Thursday	10-12	Karen Jurasek	CCCSWPIG	N055
Thursday	12-2	Dr. Volker	CP	N055
Thursday	12-2	Yuh-soon Park	CCCS	Micro
Thursday	12-2	_____	CCCSW	TV
Thursday	12-2	Karen Jurasek	CCCSWPIG	301

## Treatment Information Sheet

Day & time: **Monday 10-12**

Facilitator: **Jody Rude**

Room: **Micro**

Section #: **11**

treatment: **CP**

Electricity Folder: **1**

Treatment start time \_\_\_\_\_:

Treatment end time \_\_\_\_\_:

Total minutes \_\_\_\_\_

Comments & remarks concerning treatment:

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Facilitator signature

**\* *Be sure to collect ID Cards***

**Facilitator Instructions**

1. Before class, check computers in assigned experiment room  
  
    \_\_\_\_\_ Electricity 1 folder is showing and has electricity stack  
  
    \_\_\_\_\_ Electricity 2 folder is showing and has electricity stack
2. Report to the 301 classroom to pick up students and experiment packets.
3. Go to assigned experiment rooms, have students sit at computers, and write section number on the board
4. Read instructions to students (BE ENTHUSIASTIC)
5. Read and do mouse directions (if needed)
6. Pass out Black Out article for students to read before starting Electricity lesson. **NOTE:** no articles are needed for CCCSWPIG sections
7. RECORD START TIME (start clock when reading begins)
8. Assist students as needed; do not give answers to content questions, instead direct their thinking to find their own answers.
9. Monitor time, (remember- 50 minutes are allowed for reading and lesson before the test)
10. RECORD FINISH TIME OF LAST STUDENT
11. Give students ID cards, test and answer sheet (remember, 50 minutes are allowed for test)
12. Collect ID cards, test and answer sheet, put in experiment packet and return to 301 classroom.
13. Return computers to original state
  - "Quit" Hypercard (Apple - Q)
  - close folder(s)
  - leave computers on

Directions for Conceptual Change Computer Simulation & Writing  
(CCCSW)

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

There are two parts to today's electricity activities: an article on the New York black out and the computer-based lesson. Before beginning the computer-based lesson, please read the article. Throughout the electricity lesson, you will be asked questions that appear in bold type. Some of the questions require you to be creative and resourceful. Please critically think through your answers and write them in the journal provided. You may also be asked to do some basic arithmetic, please perform all of the calculations. You can use space in your journal for your calculations. Also in the electricity lesson, you may see individual words that appear in bold type, by clicking on these words you can access their definitions. Lastly, please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience.

If you have questions through the lesson, please raise your hand and I will assist you. When you complete the lesson, please bring your journal scratch paper to the front and pick up a test. You will have 50 minutes to complete the lesson and 50 minutes to complete the test. Your performance with the lesson and the test will in no way affect your course grade.

**Directions for Conceptual Change Computer Simulation (CCCS)**

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

There are two parts to today's electricity activities: an article on the New York black out and the computer-based lesson. Before beginning the computer-based lesson, please read the article. Throughout the electricity lesson, you will be asked questions that appear in bold type. Some of the questions require you to be creative and resourceful. Please critically think through your answers to these questions. You may also be asked to do some basic arithmetic, please perform all of the calculations. You can use the Amazing World of Electricity Scratch Paper for your calculations. Also in the electricity lesson, you may see individual words that appear in bold type, by clicking on these words you can access their definitions. Lastly, please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience.

If you have questions through the lesson, please raise your hand and I will assist you. When you complete the lesson, please bring your scratch paper to the front and pick up a test. You will have 50 minutes to complete the lesson and 50 minutes to complete the test. Your performance with the lesson and the test will in no way affect your course grade.



### Directions for Computer Presentation (CP)

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

There are two parts to today's electricity activities: an article on the New York black out and the computer-based lesson. Before beginning the computer-based lesson, please read the article. Throughout the electricity lesson you may be asked questions or to do some basic arithmetic, please critically think through the answers to questions and perform all of the calculations. You can use the Amazing World of Electricity Scratch paper for these purposes. Also in the electricity lesson, you may see individual words that appear in bold type, by clicking on these words you can access their definitions. Lastly, please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience.

If you have questions through the lesson, please raise your hand and I will assist you. When you complete the lesson, please bring your scratch paper to the front and pick up a test. You will have 50 minutes to complete the lesson and 50 minutes to complete the test. Your performance with the lesson and the test will in no way affect your course grade.

## Mouse Directions - Electricity Folder # 2 (for treatments CCCS & CCCSW only)

How many of you are familiar with a Macintosh computer and a mouse?

To assist you in operating the computer-based electricity lesson, we will go over the operations of a mouse. The mouse is the device you will use to access information on the computer. The mouse is located on the right side of the key board and is connected to the computer by a thin cable. When the cable connection on the mouse is headed toward the computer, the mouse is right-side-up. Pick up the mouse and look at it's bottom. See the ball on the mouse? The mouse uses the ball to move an arrow around the screen of the computer. Move the ball in a circle and look at the screen. You should see an arrow moving around. This is how the mouse accesses information in the computer. Set the mouse down and use it to move the arrow around the screen. This is how a mouse works.

There are 3 skills you need to use a mouse and the electricity lesson. They are Pointing, Clicking and Dragging. Pointing is the process of moving the arrow to a specific location or object on the screen. Move the arrow (via the mouse) to the hard drive in the upper right corner. Place the arrow directly on the hard drive label. Point directly to the first letter on the label. Move the mouse to the keyboard icon in the center of the screen. This is pointing. Pointing is moving the arrow to a specific location or object on the screen.

Clicking is the process of accessing an object or information in the computer. Notice the rectangle near the top of the mouse, this is the mouse button and is used for clicking. You press down on the rectangle to "click on" and access an object. Before clicking on an object, you must "Point" to it. Point to the rectangle above the hard drive label on your screen. This is the Hard Drive. Click on the hard drive. Notice it turns dark; you have selected and can access the hard drive. To "de-select" the hard drive, click anywhere on the screen except on the hard drive. Click off of the hard drive and click on the folder "Electricity 1". Now click off of "Electricity 1" Now click on the Hard Drive and then on the Electricity 1 folder. This is clicking. You click to access an object or get information in the computer.

The last skill you need to learn is Dragging. Dragging is the process of moving an object around the screen. In order to drag an object, you must click on the object, hold down the mouse button, and move the mouse. Click and hold on the hard drive, now move the mouse around. Drag the hard drive to the top left corner of the screen. This is dragging. Now "DRAG" the hard drive to the center of the screen.

### Practice

Click on the folder "Electricity 1" Point to the folder "Electricity 2". Now drag the hard drive back to the top right corner. You've got it, Pointing, Clicking and Dragging- the three skills you will need for this lesson. Now click twice on the Electricity 2 folder. The folder should open up. Point to the icon labeled "Electricity 2". When you are ready to begin the computer lesson, click twice on this icon. Again, please begin by reading the article and then start the computer program.

- Screen saver is O.K.

## Mouse Directions - Electricity Folder # 1 (for treatment CP only)

How many of you are familiar with a Macintosh computer and a mouse?

To assist you in operating the computer-based electricity lesson, we will go over the operations of a mouse. The mouse is the device you will use to access information on the computer. The mouse is located on the right side of the key board and is connected to the computer by a thin cable. When the cable connection on the mouse is headed toward the computer, the mouse is right-side-up. Pick up the mouse and look at it's bottom. See the ball on the mouse? The mouse uses the ball to move an arrow around the screen of the computer. Move the ball in a circle and look at the screen. You should see an arrow moving around. This is how the mouse accesses information in the computer. Set the mouse down and use it to move the arrow around the screen. This is how a mouse works.

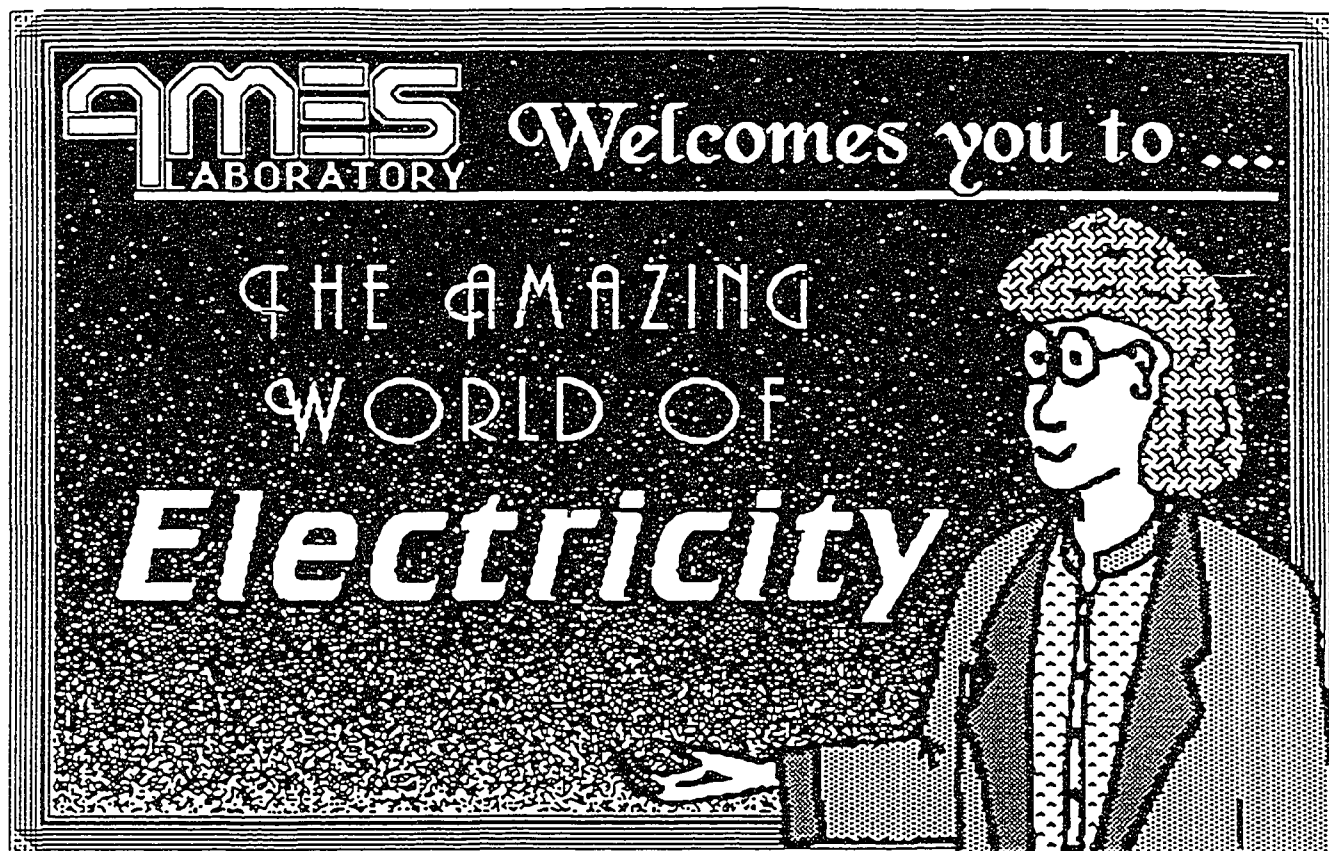
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### Practice

Click on the folder "Electricity 1" Point to the folder "Electricity 2". Now drag the hard drive back to the top right corner. You've got it, Pointing, Clicking and Dragging- the three skills you will need for this lesson. Now click twice on the Electricity 1 folder. The folder should open up. Point to the icon labeled "Electricity 1". When you are ready to begin the computer lesson, click twice on this icon. Again, please begin by reading the article and then start the computer program.



## Student Journal

Two digit section #

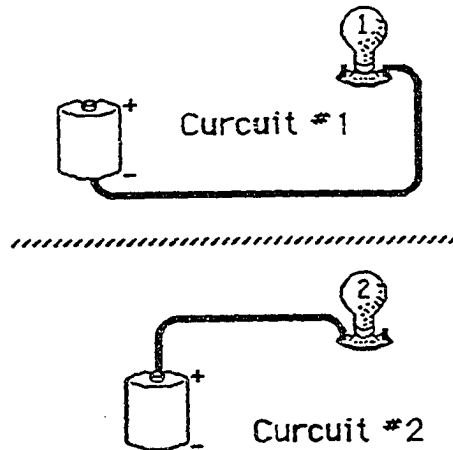
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Last 4 digits of SS #

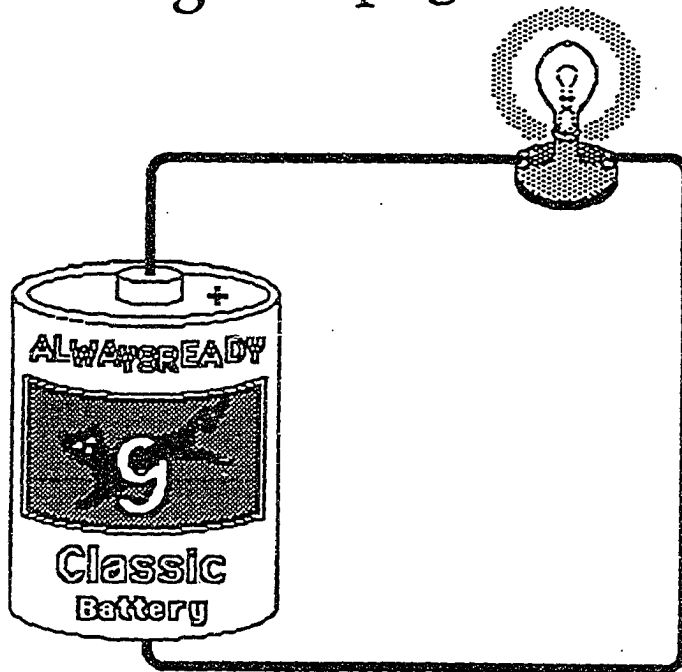
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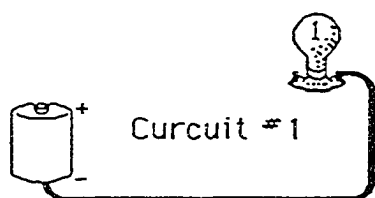
This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

If your simulation circuit looks like circuit 1 or 2,  
**go to page 3.**



If your simulation circuit looks like circuit 3,  
**go to page 4.**



Sink Theory

Will circuit 1 cause the bulb to light? \_\_\_\_\_

Describe how the electrical energy in circuit 1 flows to justify your answer.

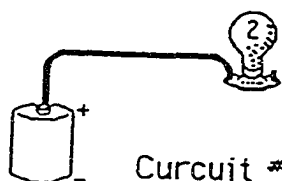
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Will circuit 2 cause the bulb to light? \_\_\_\_\_

Describe how the electrical energy in circuit 2 flows to justify your answer.

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What is the difference between circuit 1 and 2?

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What did you learn about how a circuit is constructed and how electricity flows in a circuit?

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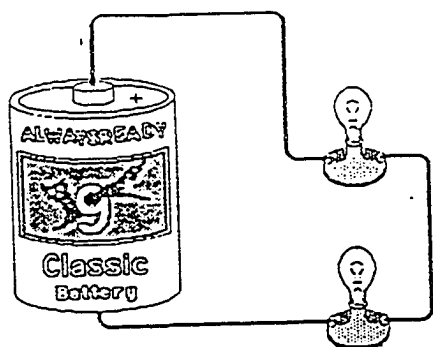
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How is this different from what you previously thought about circuits?

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242

### Clashing Current Theory

In this circuit there are two light bulbs at different locations within the circuit.

Will the circuit cause the both bulbs to light? \_\_\_\_\_

Describe how the electrical energy in the circuit flows to justify your answer.

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What happened when the circuit was completed in the simulation?

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What did you learn about how a circuit is constructed and how electricity flows in a circuit?

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How is this different from what you previously thought about circuits?

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Measuring Electricity

Ohms' Law       $I = \frac{V}{R}$

Car battery = 12 volts

The resistance for the parking lights is 3 ohms.

When the parking lights are on, how much current is generated?

The radio in this same car generates a current of 6 amperes.

What is the resistance of the radio?

One evening while waiting in the car for a friend, you decide to play the radio and keep the headlights on.

Given the information above, calculate the resistance and the current needed to operate both the headlights and the radio.

Given the information above, what is the difference in current needed to operate the parking lights and radio as compared to the headlights and radio?

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244  
Series Circuits

Given what you have learned about the way circuits operate and how current moves through a circuit, is it possible to construct a series circuit with four televisions where three televisions work and one does not?

\_\_\_\_\_

Many students think that it is possible to construct a series circuit with four televisions in which three of the televisions work and one does not. Do you think that these students are correct? \_\_\_\_\_

Describe/sketch the circuit that justifies your answer. Describe how the current flows within your circuit.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Describe what happens to the televisions when all of the switches are in the ON position.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Series Circuits cont.

Describe what happens to the televisions when one of the switches is moved to the OFF position.

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Describe what occurred physically in the circuit when one of the switches is moved to the OFF position and how current flows through the circuit.

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What did you learn about series circuits?

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How is this different from what you previously thought?

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Dispersion of Electrical Energy in Series Circuits

Given your knowledge of how series circuits operate and how current moves through a circuit, do you think that there will be a difference in the brightness of the bulbs when the circuit is switched on? \_\_\_\_\_

Which bulb will be the brightest? \_\_\_\_\_

Which one will shine the least? \_\_\_\_\_

Will they have the same brightness? \_\_\_\_\_

Describe how you think the current flow will affect the brightness of the bulbs.

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Are the students who believe bulbs 1 and 2 or bulbs 3 and 4 will vary in brightness correct? Explain why or why not.

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Dispersion of Electrical Energy in Series Circuits cont.

Given the resistance of each bulb and the voltage of the batteries, calculate the amount of current needed for each bulb. (Remember,  $I = V/R$ .)

Is there a difference in the brightness of the four bulbs? \_\_\_\_\_

Record the 5 ammeter readings for the current throughout the circuit.

1.                      2.                      3.                      4.                      5.

Calculate the current needed for the entire circuit.  
(Remember,  $R = R_1 + R_2 + R_3 + R_4$ ;  $I = V/R$ )

What is the difference between the current calculated for each individual bulb and all four bulbs together? \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

What did you learn about dispersion of electricity within a series circuit?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

How is this different from what you previously thought about dispersion of electricity within a series circuit?

\_\_\_\_\_

\_\_\_\_\_

Dead Battery

Given what you have learned about electric circuits, current, and electromotive force, explain what you think occurs when a battery is "dead".

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Which device (toaster, fan, and light bulb) do you think will consume the greatest amount of electromotive force and why?

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Record the readings from each voltmeter.

1.                      2.                      3.

Remembering that current flows from negative to positive, what do the readings tell you about the amount of electromotive force after each device?

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What did you learn about dead batteries?

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How is this different from what you previously thought about dead batteries?

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Secondary/Elementary Education 301  
Media For Teachers

Computer-based Instructional Activity  
Assignment

Last week you participated in a computer-based instructional activity on electricity. The lesson was an example of how computer technology can be used in education.

Please discuss in 3-5 paragraphs how this kind of lesson could be integrated into a classroom. Specifically, describe a specific educational situation (include grade level, subject area, number of students in the class, ratio of students to teachers, and the kinds of students, i.e. gender, racial background, socioeconomic levels, etc.) and discuss how you would use the type of computer application you experienced in the classroom.

You may want to include in your discussion various features of a computer-based instructional application that may be important to your situation. These may include animation, graphics, sound, or the ability to simulate real-world experiences.

## TROUBLE SHOOTING THE ELECTRICITY COMPUTER PROGRAM

### Function keys

The computer-based instruction for this study is one program that has two branches: the **presentation branch** for CP sections and the **simulation branch** for CCCS, CCCSW, and CCCSWPIG sections. The branch setting has been preset, so be sure and follow the folder information on the Treatment Information Sheet. If you need to alter the branch setting, use the F15 key. If you need to move to specific locations within the system, use the following function key commands:

- F1 - Simulation (not for CP group)**
- F2 - Voltage (beginning of measuring electricity)**
- F3 - Series Circuits**
- F4 - Dispersion**
- F5 - Dead Batteries**
- F14 - Cancels facilitator prompts (may appear with CCCS & CCCSW)**
- F15 - Sets instructional mode (presentation or simulation)**

If a student gets into the wrong folder or gets lost within the computer activity, you can use the function keys to get them back to the right location. If this is not possible or if a student has any problems with the computer activity that you can't solve, simply quit the program by selecting **Apple - Q**. You can then re-boot the program and the student can start over.

To move forward to the next card, use  
To move to previous card, use

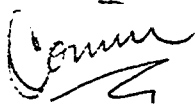
**Apple- 3**  
**Apple- 2**

If you begin to have problems with the copy of the application that is in your designated folder, there is an extra copy on the hard drive. Open the "**Electricity Back-up**" folder *IN* the hard drive and select the application within the folder that matches your treatment section (i.e. CP or CCCS, CCCSW, and CCCSWPIG). In addition, there are copies of the computer program in Electricity envelope near the front of the room. If necessary, re-load the computer with the disc copy of the simulation.



Date: August 24, 1992

To: Dr. Volker, Dr. Simonson, Denise Schmidt, Yuh-soon Park,  
Karen Jurasek, Terry Corwin, Dawn Poole, Kayt Sanwood,  
Jody Rude

From: Connie Hargrave 

RE: Training sessions for computer simulation study

The purpose of this memo is to remind you of the training sessions for the computer simulation study that will be incorporated into EI/Sec Ed 301. Training sessions will be held **12 - 2 p.m. on Tuesday August 25** and **6 - 8 p.m. on Wednesday August 26** in the IRC. If you are unable to attend one of these sessions, please contact me (4-9682).

Attached is a list of times you are scheduled to assist with the study. (The time(s) you teach are not included.) Please verify the accuracy of these times with your records.

Thank you for volunteering to assist with my study concerning preservice teachers' misconceptions of electricity.

## TA TRAINING SESSION

## I. Welcome/Greeting

Hello and thank you for coming. The purpose of this meeting is to prepare you to facilitate the treatment for my study.

## II. Verify facilitator schedules

Let's begin by going over the schedule of extra times you volunteered to facilitate. Is this accurate???

Who teaches 301 when? Complete facilitator schedule

## III. Pretest announcement - display &amp; handout wk.

The week of September 7-11, I will come to your class to introduce the study. I will give a five minute overview and then ask the students to take an interest and experience inventory. This will take approximately 30 minutes. I will come at the second hour of class.

If you teach on Monday, I will come and do the overview on August 31. → communication & visual literacy

## IV. Treatment announcements

## CCCSW treatment

Review study- title, purpose, and hypothesis.

When you are TA, you will facilitate the CCCSW section.

The CCCSW treatment is:

- ~~reading of Black out article~~
- computer-based lesson w/ conceptual change designed text, simulations, and writing of answers to conceptual change questions

## Other treatments (CP &amp; CCCS)

The CP treatment is:

- ~~reading of Black out article~~
- computer-based lesson with traditional text design

The CCCS treatment is:

- ~~reading of Black out article~~
- computer-based lesson w/ conceptual change designed text and simulations

## V. Review of facilitator tasks, go through handout &amp; "EXPERIMENT PACKET."

- ROOM DESIGN
- 301 Review Activity for QUIZ POINTS

VI. Questions????????? — Mtg. Friday Sept. 11 — To review & make sure everyone is ready!!!!

VII. Go through simulations with Connie modeling facilitator tasks

VIII. TA's document errors in simulation

9:00 A.M.

**H3: Materials for Facilitator Training Session 2**

# The Amazing World of Electricity

Computer simulations, reflective journals, peer group interactions, and conceptual change about electricity with preservice teachers

Study by Connie P. Hargrave

Facilitator Materials  
September, 1992

Facilitator Instructions

1. Before class, pick up treatment packet and check computers in assigned room
  - \_\_\_\_\_ Electricity 1 folder is showing and has electricity 1 stack
  - \_\_\_\_\_ Electricity 2 folder is showing and has electricity 2 stack
2. Report to the 301 classroom to pick up students and test packets.
3. Go to assigned experiment rooms, have students sit at computers, and write section number on the board
4. Pass out scratch paper or journals (instruct students not to flip through journal)
5. Read instructions to students (BE ENTHUSIASTIC)
6. Read and do mouse directions (if needed)
7. RECORD START TIME (start clock when reading begins)
8. Assist students as needed; do not give answers to content questions, instead direct their thinking to find their own answers.
9. Monitor computer time, (remember- 45 minutes minimum and 1 hour maximum)
10. RECORD COMPUTER FINISH TIME OF LAST STUDENT
11. Give students ID cards, test and answer sheet (remember, 40 minutes are allowed for test)
12. Collect ID cards and answer sheet, -- put in treatment packet  
Put Tests and pencils in test packet and return to both envelopes to 301 room
13. Return computers to original state
  - "Quit" Hypercard (Apple - Q)
  - close folder(s)
  - leave computers on

IF you use F Keys - MUST hit F14

## Treatment Instructions

Directions for Computer Presentation (CP)

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

Today's activity is an individual computer-based instructional experience. The instruction will appear on the computer screen, so read each screen carefully. Throughout the computer-based instruction you may hear different sounds from the computers in the room. Please ignore the sounds you hear from other computers and concentrate on your own. Don't worry that you are not keeping up with your neighbor as everyone will be in a slightly different place. Remember this is an individual instructional activity, so please do not consult with your neighbor. Focus on your own work.

Throughout the electricity lesson, questions or directions may pop-up on the screen. You **DO NOT** have to write out the answers to these questions. Instead, critically think through the answers to the questions/directions that pop-up and **then** click "OK" to continue. In addition to the questions that may pop-up on the screen, you may be directed to perform some basic arithmetic calculations. Please perform all of the calculations. You can use the paper provided for this purposes. Again, you do not have to write out the answers to the questions, but you **must** critically think through your answer before clicking "OK" to continue. Please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience. Last, it may seem as though you are at the end of lesson before you actually are; when the words "Thank You" appear on the screen you have completed the lesson.

If you have questions through the lesson, please raise your hand and I will assist you. When you complete the lesson, please bring your scratch paper to the front and pick up a test. Take your time going through the system and try to learn as much as you can. You must spend at least 45 minutes on the lesson and but no more than 1 hour. You will have 40 minutes to complete the test.

**Directions for Conceptual Change Computer Simulation (CCCS)**

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

Today's activity is an individual computer-based instructional experience. The instruction will appear on the computer screen, so read each screen carefully. Throughout the computer-based instruction you may hear different sounds from the computers in the room. Please ignore the sounds you hear from other computers and concentrate on your own. Don't worry that you are not keeping up with your neighbor as everyone will be in a slightly different place. Remember this is an individual instructional activity, so please do not consult with your neighbor. Focus on your own work.

Throughout the electricity lesson, questions or directions may pop-up on the screen. You **DO NOT** have to write out the answers to these questions. Instead, critically think through the answers to the questions/directions that pop-up and *then* click "OK" to continue. In addition to the questions that may pop-up on the screen, you may be directed to perform some basic arithmetic calculations. Please perform all of the calculations. You can use the paper provided for this purposes. Again, you do not have to write out the answers to the questions, but you *must* critically think through your answer before clicking "OK" to continue. Please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience. Last, it may seem as though you are at the end of lesson before you actually are; when the words "Thank You" appear on the screen you have completed the lesson.

If you have questions through the lesson, please raise your hand and I will assist you. When you complete the lesson, please bring your scratch paper to the front and pick up a test. Take your time going through the system and try to learn as much as you can. You must spend at least 45 minutes on the lesson and but no more than 1 hour. You will have 40 minutes to complete the test.



Directions for Conceptual Change Computer Simulation & Writing  
(CCCSW)

Hello and welcome to the Amazing World of Electricity! -where you will learn about electricity and experience a computer-based instructional system. The purpose of this lesson is to examine the effectiveness of a computer-based instructional system to facilitate learning, so please concentrate and try to learn and understand as much as you can about electricity.

Today's activity is an individual computer-based instructional experience. The instruction will appear on the computer screen, so read each screen carefully. Throughout the computer-based instruction you may hear different sounds from the computers in the room. Please ignore the sounds you hear from other computers and concentrate on your own. Don't worry that you are not keeping up with your neighbor as everyone will be in a slightly different place. Remember this is an individual instructional activity, so please do not consult with your neighbor. Focus on your own work.

Throughout the electricity lesson, numbered questions or directions may pop-up on the screen. Please find the corresponding number and question in your journal and write the answer. Some questions have more than one part (for example, 1a, 1b, and 1c). Answer *every* part of the question before going on. Click "OK" to continue *only* after you have answered all parts of the question in your journal. In addition to the questions that may pop-up on the screen, you may be directed to perform some basic arithmetic calculations. Please perform all of the calculations. You can use the space in your journal for this purposes. If you are asked the same question more than once, please write out the answer each time you are asked.

Please feel free to take notes about the content of the lesson as we are interested in what you learn and retain from this computer-based educational experience. Last, it may seem as though you are at the end of the lesson before you actually are; when the words "Thank You" appear on the screen you have completed the lesson.

If you have questions through the lesson, please raise your hand and I will assist you. When you complete the lesson, please bring your journal to the front and pick up a test. Take your time going through the system and try to learn as much as you can. You must spend at least 45 minutes on the lesson and but no more than 1 hour. You will have 40 minutes to complete the test.

## TROUBLE SHOOTING THE ELECTRICITY COMPUTER PROGRAM

### Function keys

The computer-based instruction for this study is one program that has two branches: the **presentation branch** for CP sections and the **simulation branch** for CCCS, CCCSW, and CCCSWPIG sections. The branch setting has been preset, so be sure and follow the folder information on the Treatment Information Sheet. If you need to alter the branch setting, use the F15 key. If you need to move to specific locations within the system, use the following function key commands:

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To move forward to the next card, use	<b>Apple- 3</b>
To move to previous card, use	<b>Apple- 2</b>

If you begin to have problems with the copy of the application that is in your designated folder, there is an extra copy on the hard drive. Open the "Electricity Back-up" folder *IN* the hard drive and select the application within the folder that matches your treatment section (i.e. CP or CCCS, CCCSW, and CCCSWPIG). In addition, there are copies of the computer program in Electricity envelope near the front of the room. If necessary, re-load the computer with the disc copy of the simulation.

## Schedule for Facilitators

<u>Day</u>	<u>Time</u>	<u>Facilitator</u>	<u>Treatment</u>	<u>Room</u>
13 - Monday	10-12	Connie Hargrave	CP	Micro
23 - Monday	10-12	Terry Corwin	CCCS	TV
33 - Monday	10-12	Jodi Rude	CCCSW	301
43 - Monday	10-12	Karen Jurasek	CCCSWPIG	NO55
13 - Monday	12-2	Terry Corwin	CP	NO55
23 - Monday	12-2	Dawn Poole	CCCS	Micro
33 - Monday	12-2	Jodi Rude	CCCSW	TV
43 - Monday	12-2	Karen Jurasek	CCCSWPIG	301
Monday	2-4	XXXXXXXXXXXXDr. Volker's SectionXXXXXXXXXXXX		
12 Tuesday	10-12	Jodi Rude	CP	TV
22 Tuesday	10-12	Yuh-soon Park	CCCS	301
32 Tuesday	10-12	Dawn Poole	CCCSW	NO55
42 Tuesday	10-12	Karen Jurasek	CCCSWPIG	Micro
12 - Tuesday	12-2	Dawn Poole	CP	Micro
22 - Tuesday	12-2	Terry Corwin	CCCS	TV
32 - Tuesday	12-2	Dr. Simonson	CCCSW	301
42 Tuesday	12-2	Karen Jurasek	CCCSWPIG	NO55
12 Tuesday	2-4	Jodi Rude	CP	NO55
22 Tuesday	2-4	Yuh-soon Park	CCCS	Micro
32 Tuesday	2-4	Terry Corwin	CCCSW	TV
42 Tuesday	2-4	Karen Jurasek	CCCSWPIG	301
12 Wednesday	12-2	Jodi Rude	CP	301
22 Wednesday	12-2	Denise Schmidt	CCCS	NO55
32 Wednesday	12-2	Kayt Sunwood	CCCSW	Micro
42 Wednesday	12-2	Karen Jurasek	CCCSWPIG	TV
12 Thursday	8-10	Jodi Rude	CP	TV
22 Thursday	8-10	Denise Schmidt	CCCS	301
32 Thursday	8-10	Dawn Poole	CCCSW	NO55
42 Thursday	8-10	Karen Jurasek	CCCSWPIG	Micro

<u>Day</u>	<u>Time</u>	<u>Facilitator</u>	<u>Treatment</u>	<u>Room</u>
12 Thursday	10-12	Kayt Sunwood	CP	Micro
22 Thursday	10-12	Terry Corwin	CCCS	TV
32 Thursday	10-12	Yuh-soon Park	CCCSW	301
42 Thursday	10-12	Karen Jurasek	CCCSWPIG	N055
11 Thursday	12-2	Dr. Volker	CP	N055
21 Thursday	12-2	Yuh-soon Park	CCCS	Micro
31 Thursday	12-2	Terry Corwin	CCCSW	TV
41 Thursday	12-2	Karen Jurasek	CCCSWPIG	301

Date: September 4, 1992

From: Connie Hargrave

To: Dr. Simonson  
Dr. Volker  
Karen Jurasek  
Kayt Sunwood  
Dawn Poole  
Jodi Rude  
Yuh-soon Park  
Terry Corwin  
Denise Schmidt

RE: Computer simulation study

As you know, with your assistance I will be conducting my research study on computer simulations and students' conceptions of electricity **September 14-17.**

In preparation for that week, I want to meet with you **Friday Sept. 11 at 9:00 a.m. in Microteaching Classroom.** The purpose of this meeting will be to review the procedures for the study and apprise you of the results of the pilot tests. If you cannot attend this meeting please let me know (294-9682).

Remember: I will introduce the study the last hour of your classes and administer pretest instruments next week (**Sept 8-10**).

### Final Training session with TAs

1. Thank you very much for your assistance, support, and interest. I couldn't do it without you!!!
2. Purpose of meeting is to go over final version of how the treatments will go and make you aware of things you will need to pay particular attention to.
- 3.. **Get everyone's official class list**
4. **Go over scheduled times to facilitate to make sure everyone can make their scheduled times**
5. Approximately 10 minutes before class, go get treatment envelope in 301 room. Check computers and simulations in your assigned treatment room

#### Treatment announcements

##### **each treatment will consist of:**

- reading instructions to get everyone started (personalize the beginning stressing the importance of the study, and the need for them to do well- remind them of their 301 assignment based on this activity)
- reading mouse directions (optional- just make sure before you begin that everyone knows how to point, click and drag)
- each person must spend a minimum of 45 minutes on the computer but no more than 1 hour; if finished early- they need to review; do not pass out tests until students have been on computer for 45 minutes. Students will have 40 minutes for test.

6. Each packet will have all materials for conducting treatment- however, in the interest of trees you also will need to grab a TEST envelope when you pick up treatment envelope. (Test envelope will have posttests and pencils- be sure and return it with posttests and pencils)
7. Make sure students complete an ID card- return ID cards in treatment envelope
8. Each student should get something to write on during simulation- a journal or scratch paper
9. Folders- electricity 1 for CP group only  
electricity 2 for CCCS, CCCSW, and CCCSWPIG groups
10. remember the extra copies of treatments on each hard drive and on disk on wall
11. Important that you are familiar with path of simulations (go over concept maps)
12. everyone videotapes (tape will be in treatment envelope)

## Lessons learned from pilot tests

### mechanics of computer simulations

- I. Most of the problems with the computer portion center around the circuit building screen
  - a. students will have problems with the simulation- they need to read the screen!!!
  - b. monitor students closely until they are through circuit building section
  - c. students can get stuck in an endless loop if they don't learn (sink theory)
  - d. Only known limitation of circuit building- some students will insist on hooking up wire to negative terminal. This isn't possible. Watch for this and help them through by asking- "Why does the wire have to be hooked up to negative terminal? How does the current flow that makes this so important? & Just try it!!!" -Main thing is do not give students the answer, instead direct them back to the big idea

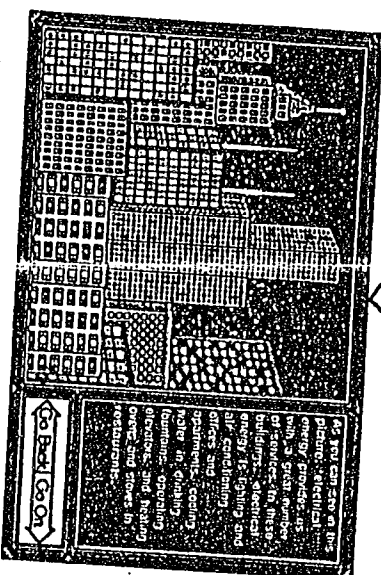
### II. Other possible difficulties

- a. some students may back up into a section they should not be in and thus get lost
- b. must instruct students that when they get a pop up question/direction, they need to complete the task and then select OK to continue

### facilitator problems in simulation

- a. If a student is confused or frustrated, go over the screen with them- get them to talk about the idea, have them read the screen aloud, break it down with them, but do not give students the answer, instead direct them back to the big idea.
- b. may need to stress individual work and no collaboration
- c. journal students should not flip through their journal
- d. journal questions are numbered and will pop up on screen so it will be real clear. They should refer to that number in their journal and answer all parts of that question before returning to the computer.
- e. be careful to watch sections students are going through in case someone gets into wrong area
- f. if you have to help someone get back to the correct section/spot use function keys \* **note- when you find the right section key hit F-14**

INTRODUCTION

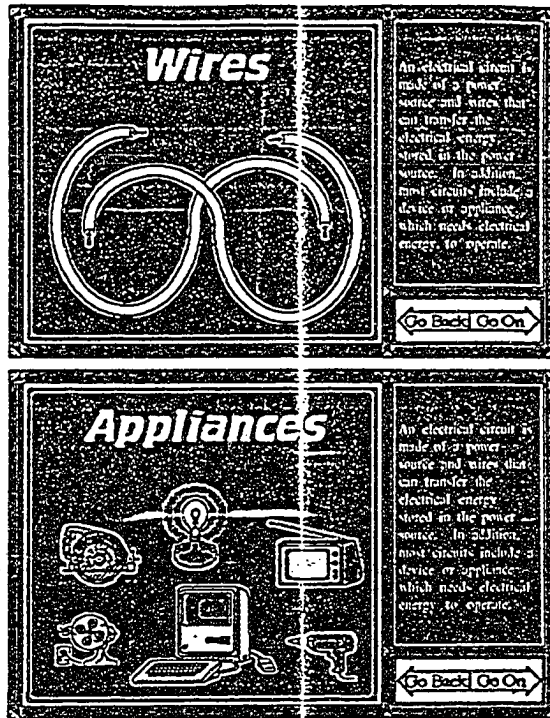


WHAT IS ELECTRICAL ENERGY  
PROTONS : ELECTRONS  
ELECTROCHEMICAL CELLS  
DRY CELLS



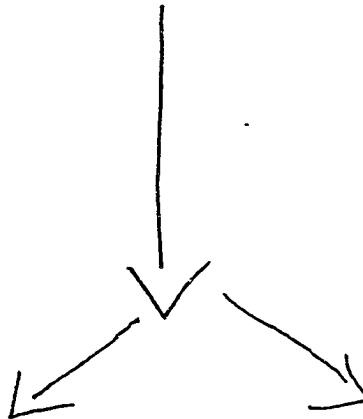
CONCEPT MAP



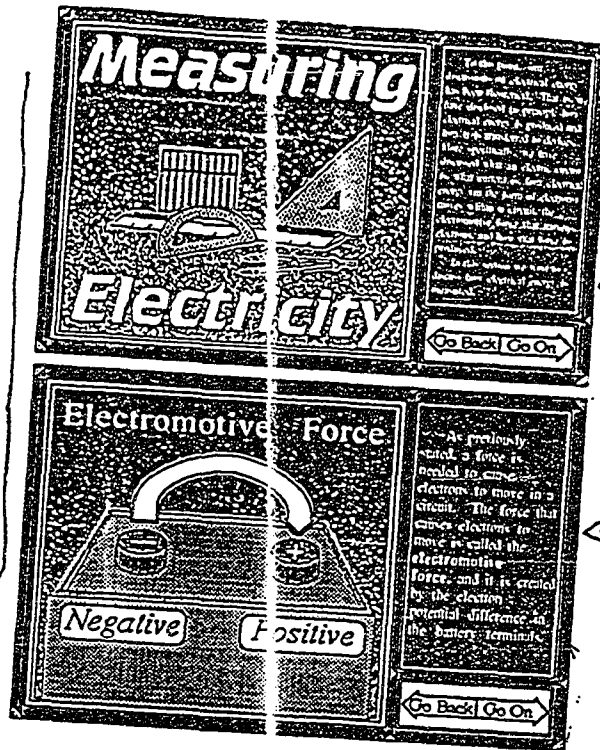


LAST  
CARDS OF  
INTRODUCTION

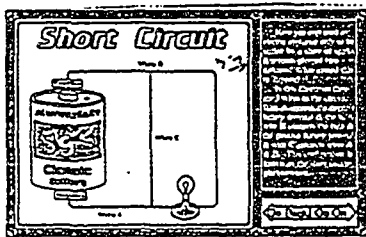
LAST  
CARDS OF INTRODUCTION



CP GROUP

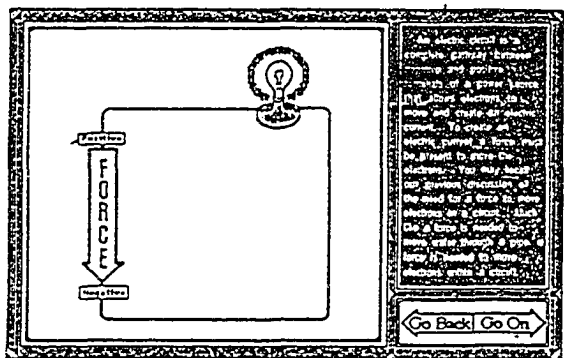
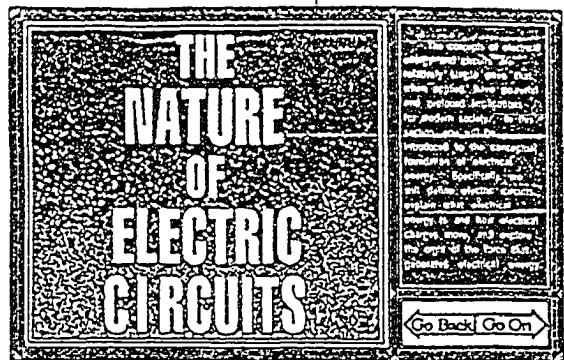
CCCS, CCCSW,  
& CCCSWPIG

F2



2

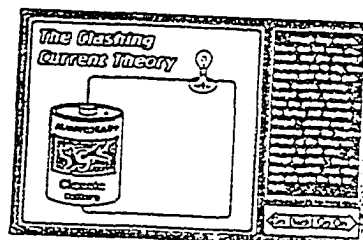
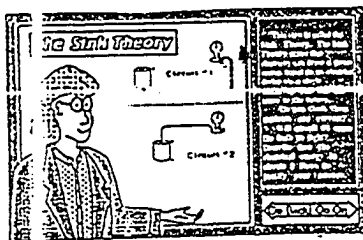
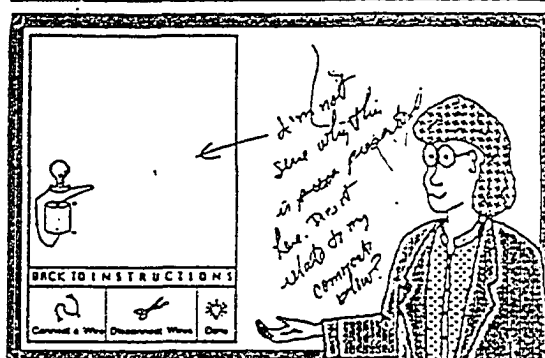
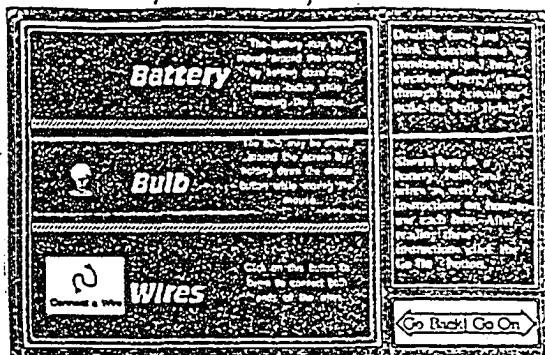
CP Group



269  
Apple-2  
IF CP, DE (F.1)

CIRCUIT BUILDING CARDS

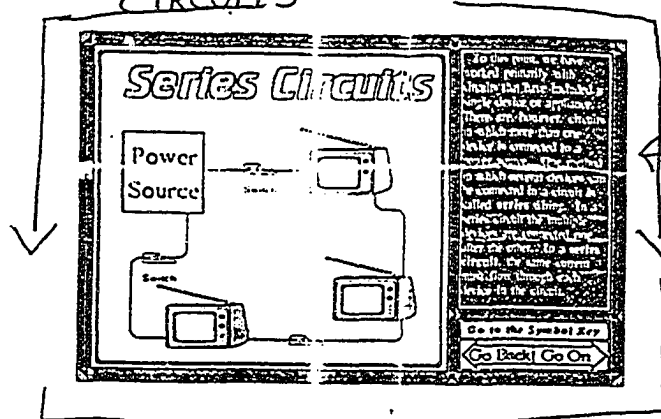
CCCS, CCCSW, & CCCSWFIG



CP  
GROUP

## SERIES CIRCUITS

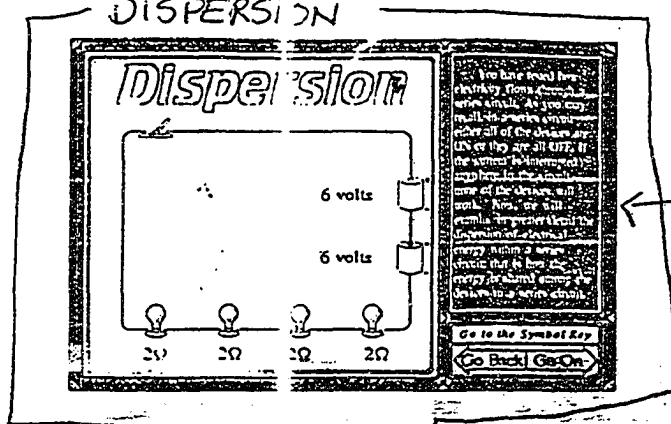
270



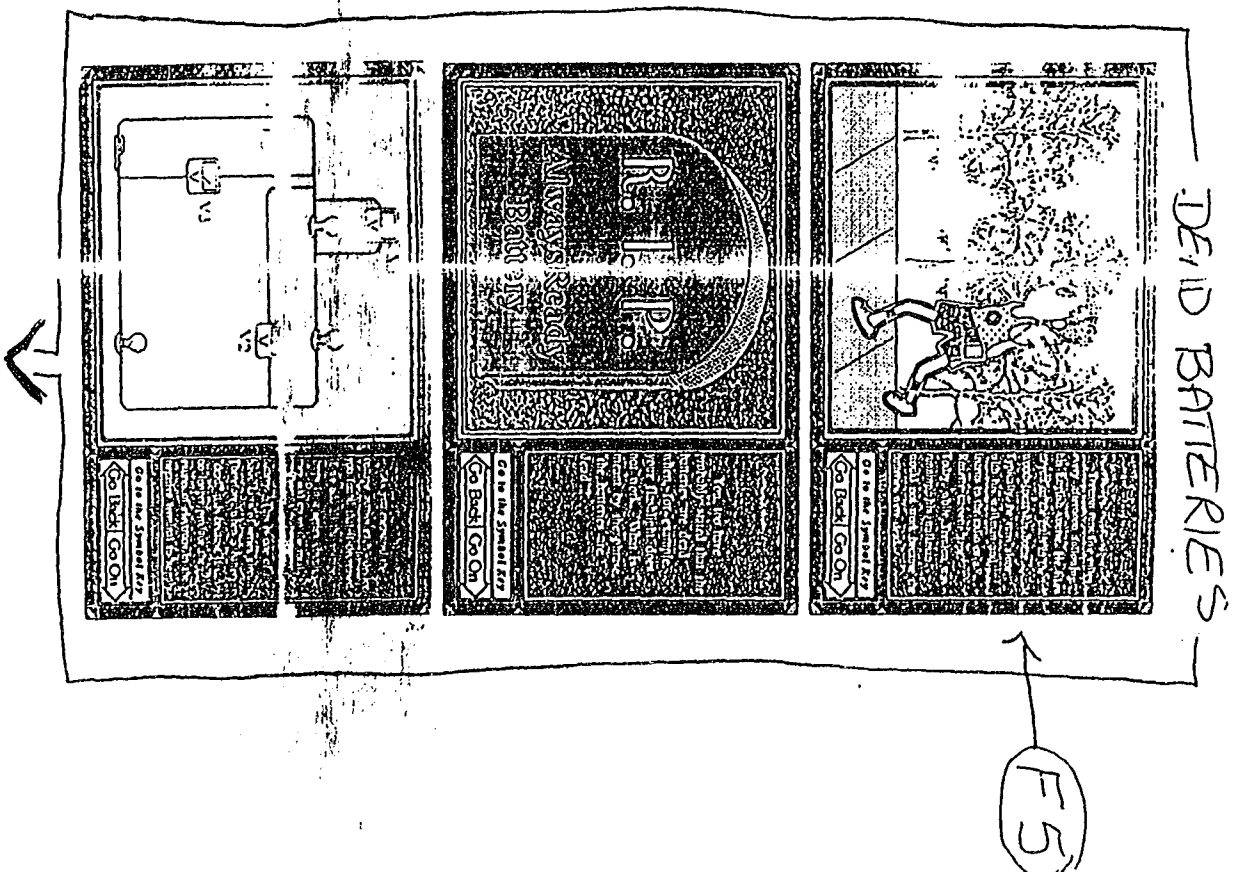
CCCS, CCCSWPIG  
CCCSIN E

F3

## DISPERSION



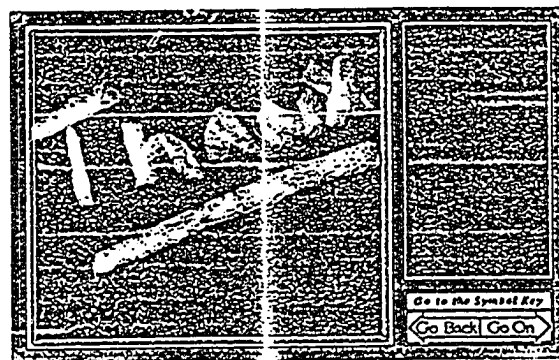
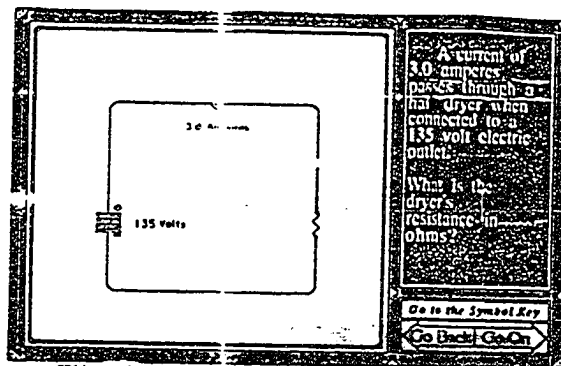
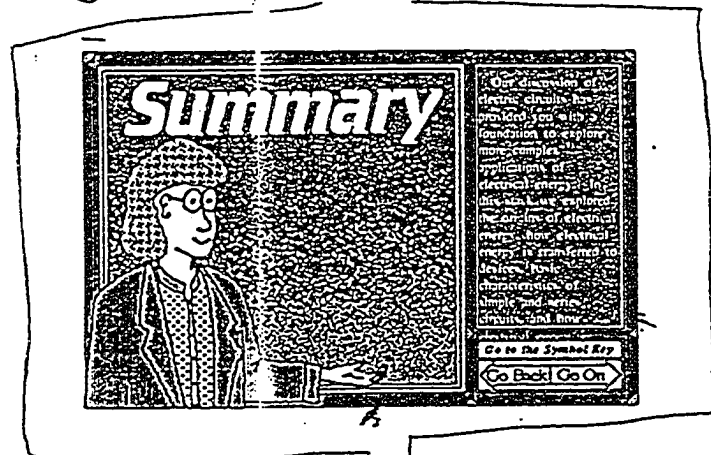
F4



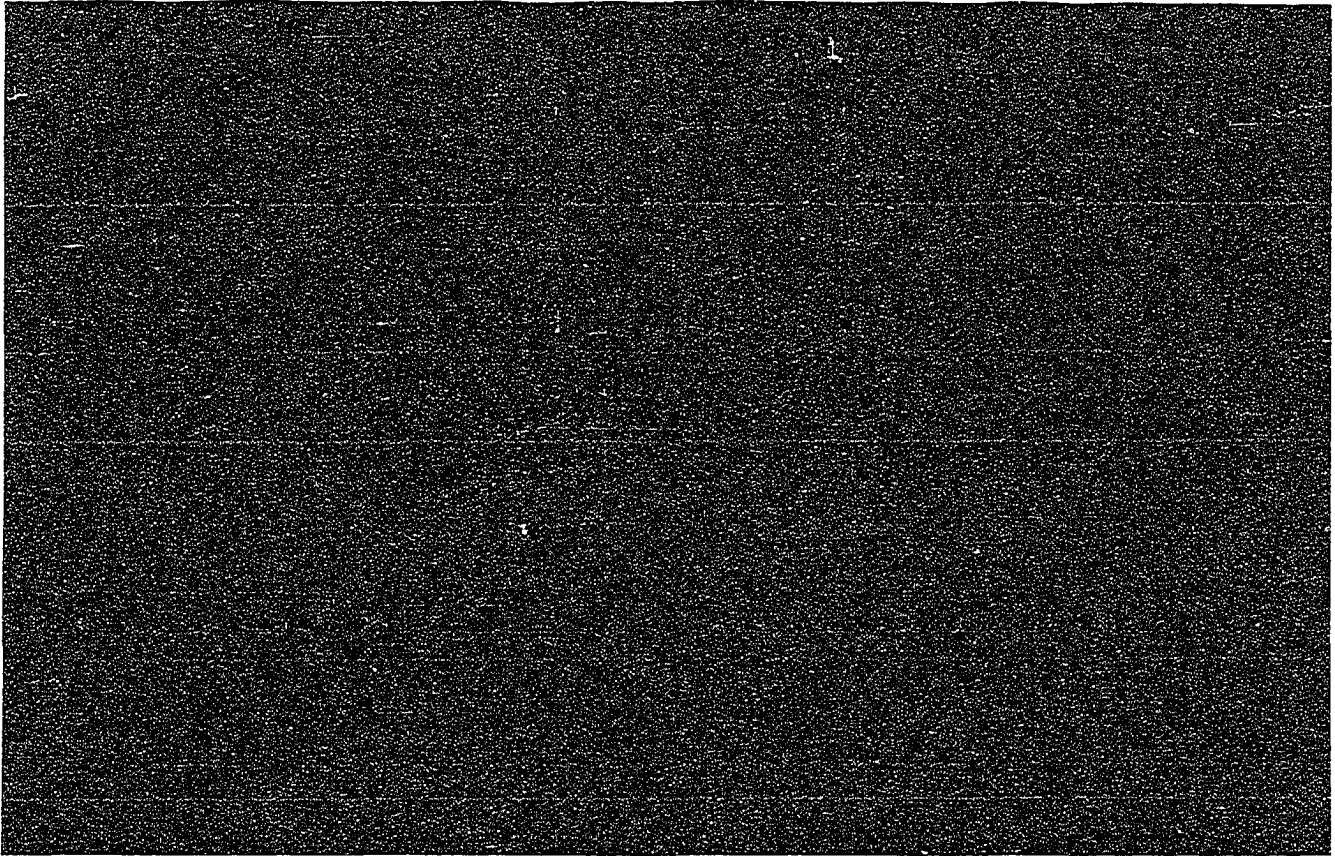
CP GROUP

SUMMARY 272

CCCS, CCCSW, CCCSWP,




APPENDIX I. COMPUTER PROGRAM SCREENS



<div data-bbox="255 1121 694 1207"><b>Comments:</b></div> <div data-bbox="255 1228 694 1767"></div>	<div data-bbox="885 1121 1324 1207"><b>Program Mode</b></div> <div data-bbox="901 1239 1308 1369"><input type="checkbox"/> Presentation Mode <input checked="" type="checkbox"/> Simulation Mode</div> <div data-bbox="885 1401 1324 1487"><b>Function Keys</b></div> <div data-bbox="885 1509 1308 1670">F1 -- Skip to Simulation F2 -- Skip to Voltage F3 -- Skip to Series Circuits F4 -- Skip to Distribution F5 -- Skip to Dead Batteries</div> <div data-bbox="885 1692 1324 1767"><b>Go Back</b></div>
---	---






Conductor



Switch



Fuse




Ammeter



Voltmeter



Resistor



Battery of Cells  
in Series

Use this card  
to identify the  
symbols that are  
used throughout  
this program.

Go Back

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Welcomes you to ...

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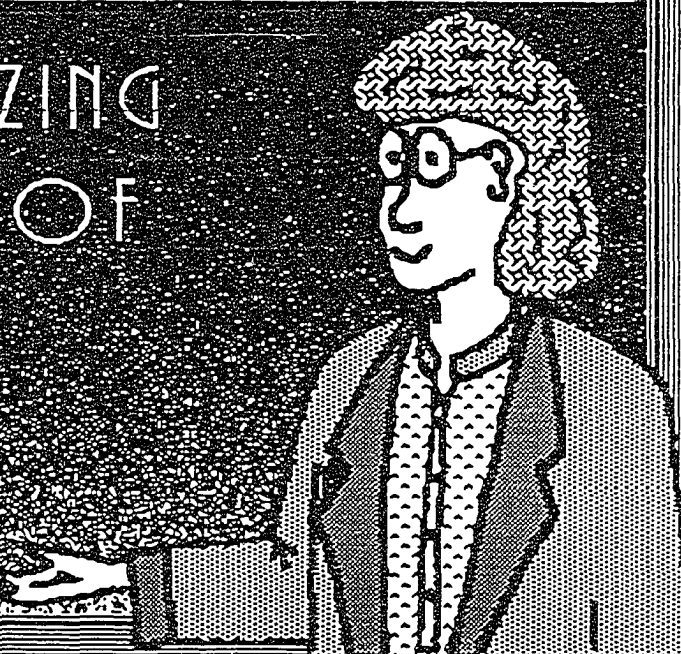




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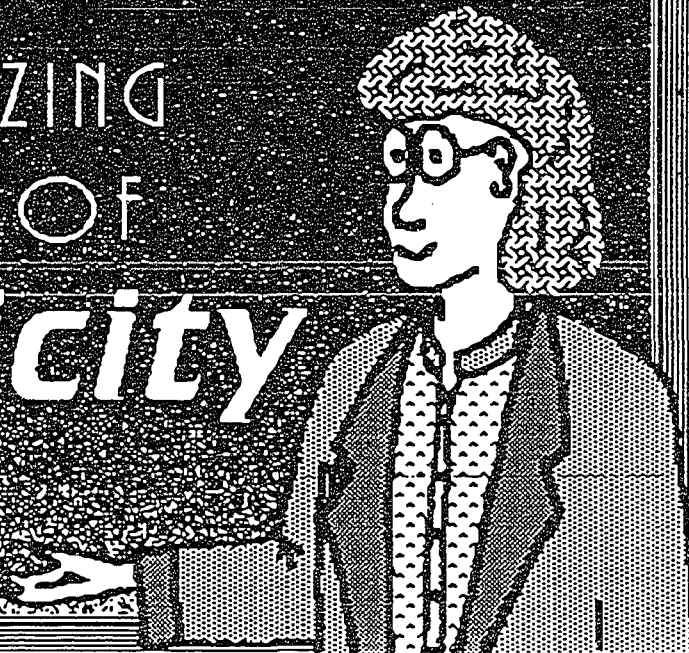
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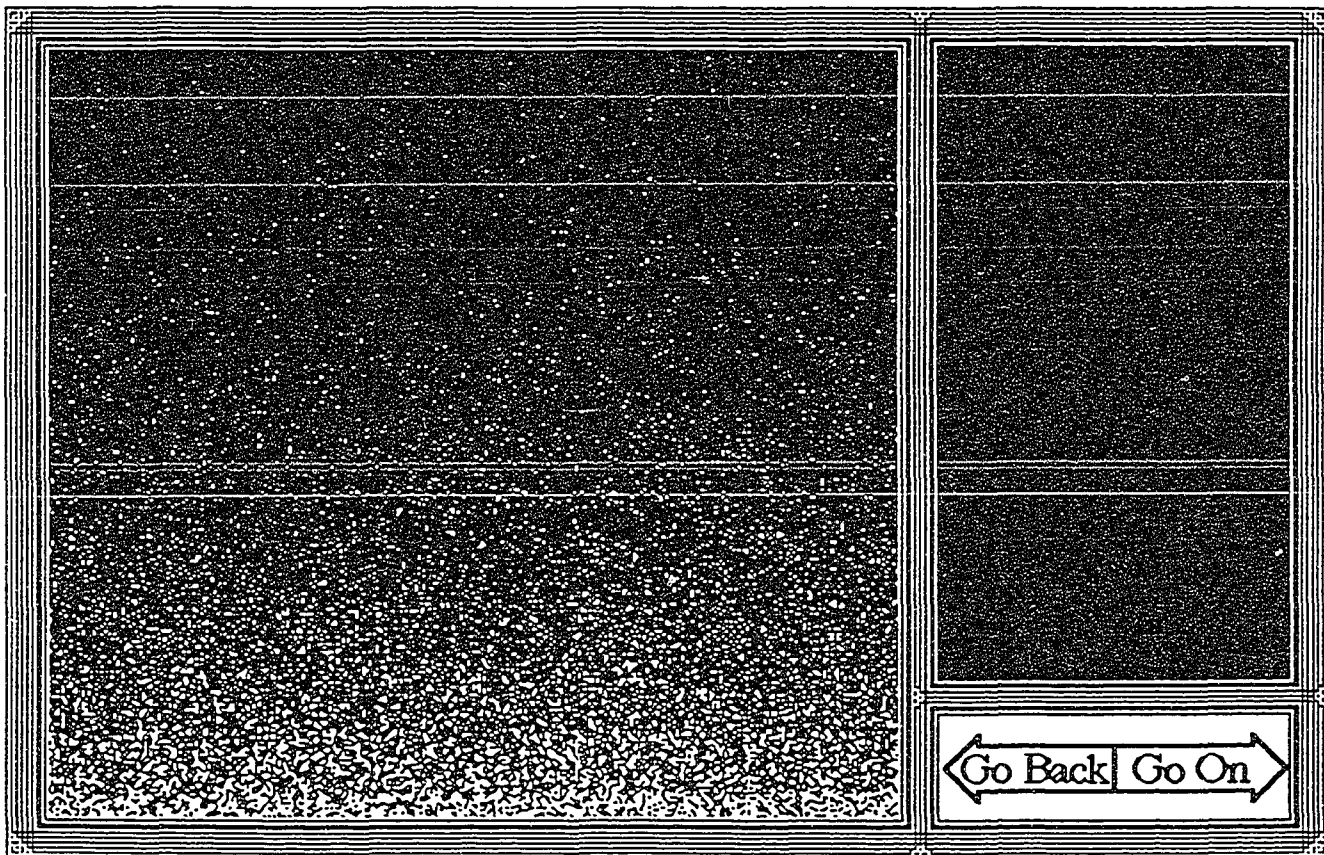
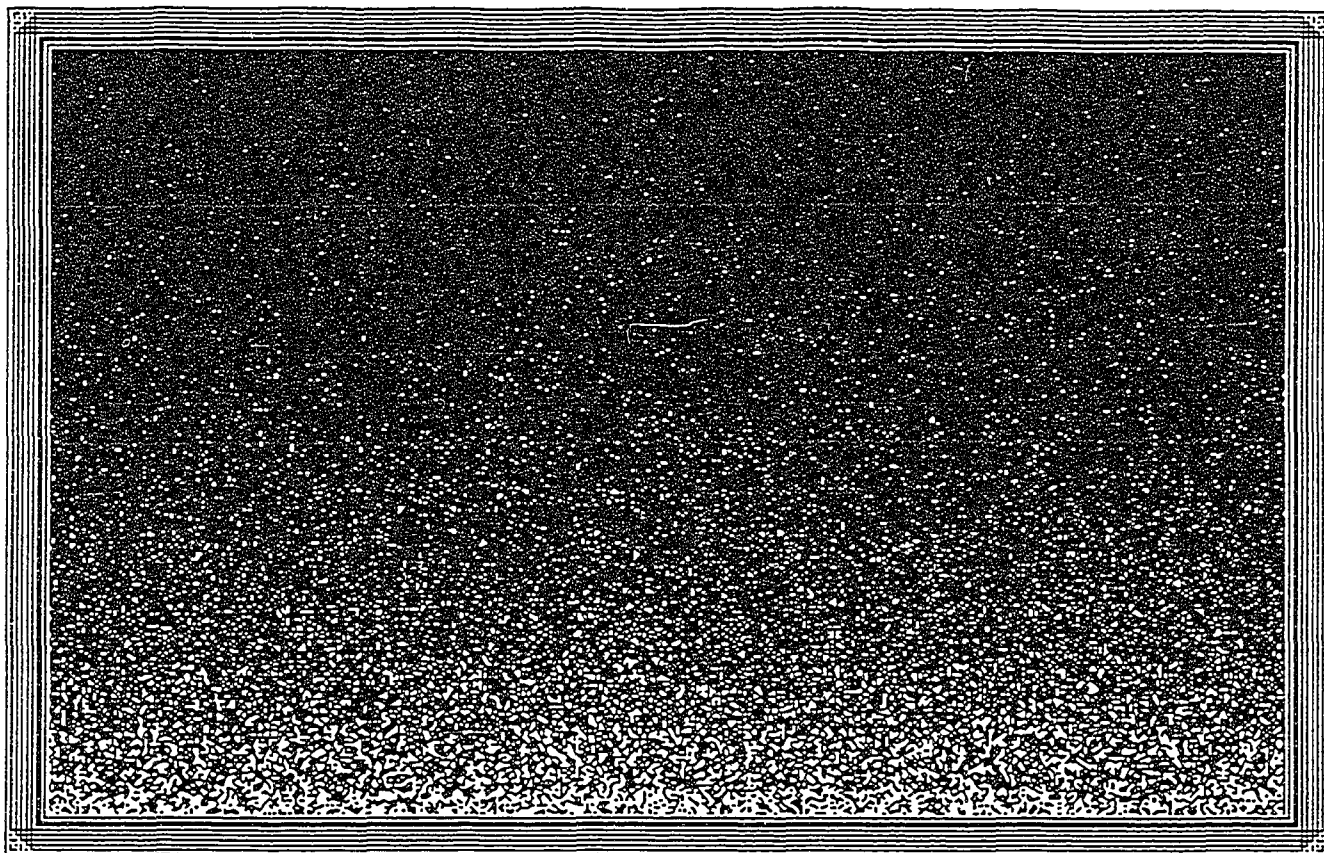
**AMES**  
LABORATORY

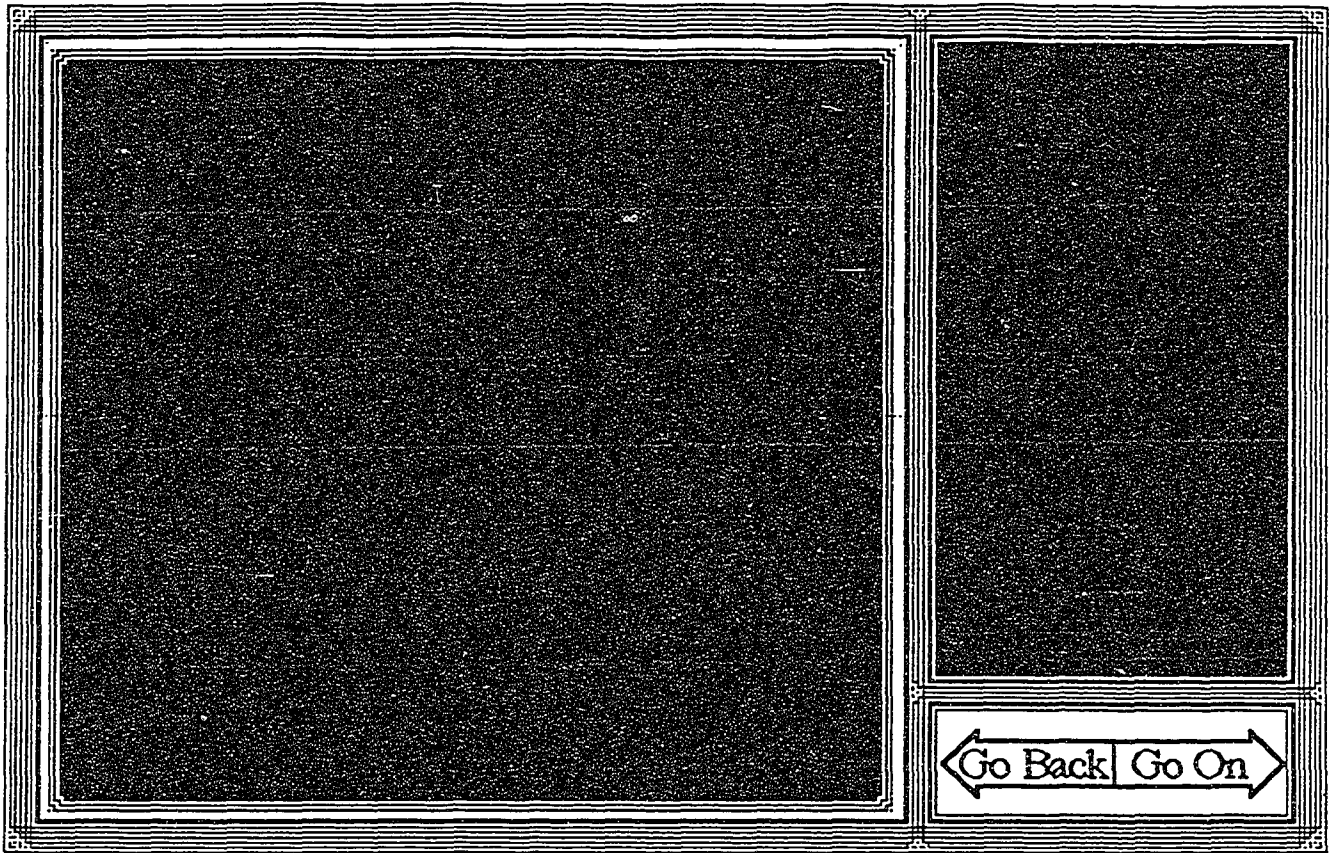
Welcomes you to ...

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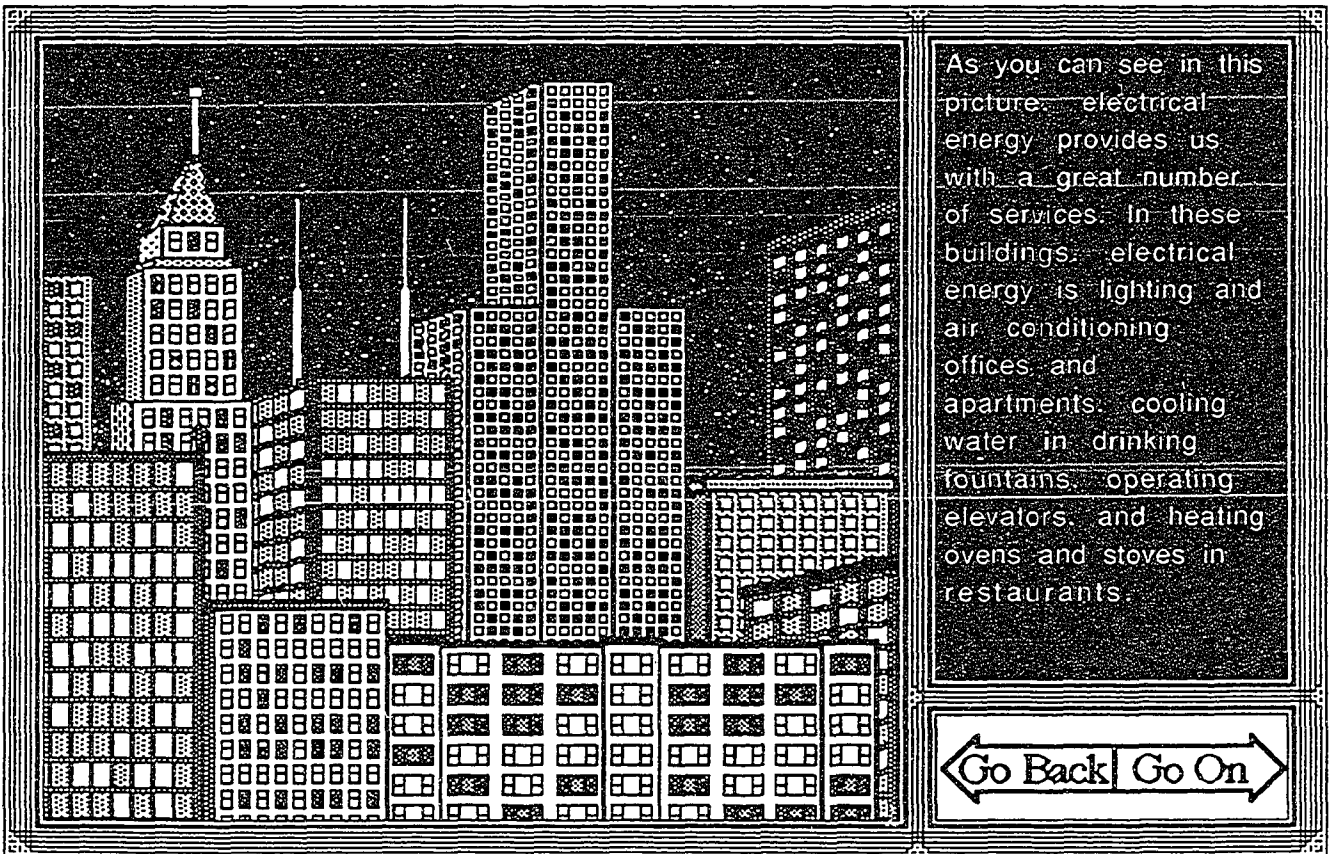








Go Back Go On



As you can see in this picture, electrical energy provides us with a great number of services. In these buildings, electrical energy is lighting and air conditioning offices, and apartments; cooling water in drinking fountains, operating elevators, and heating ovens and stoves in restaurants.

Go Back Go On



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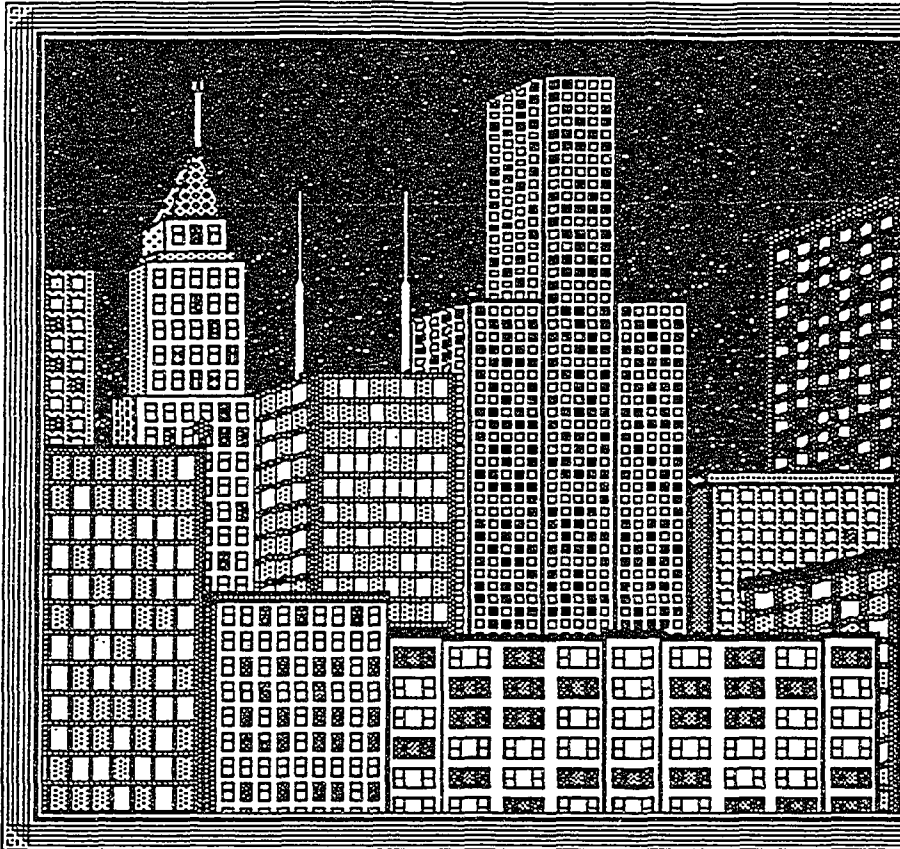
Go Back Go On



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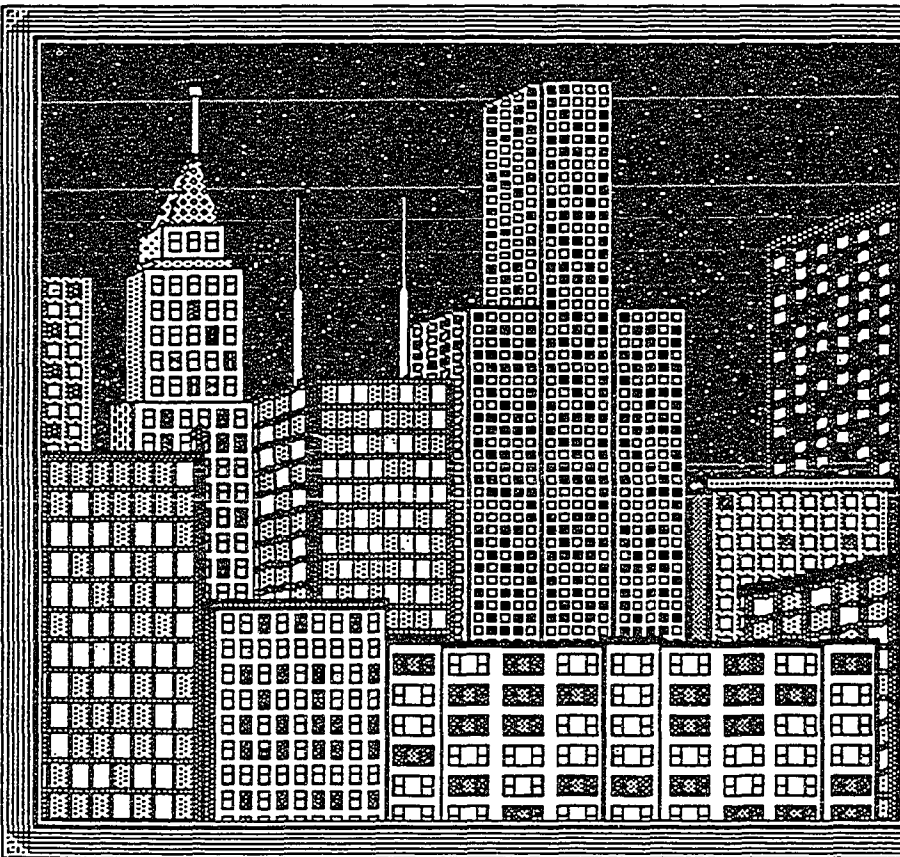
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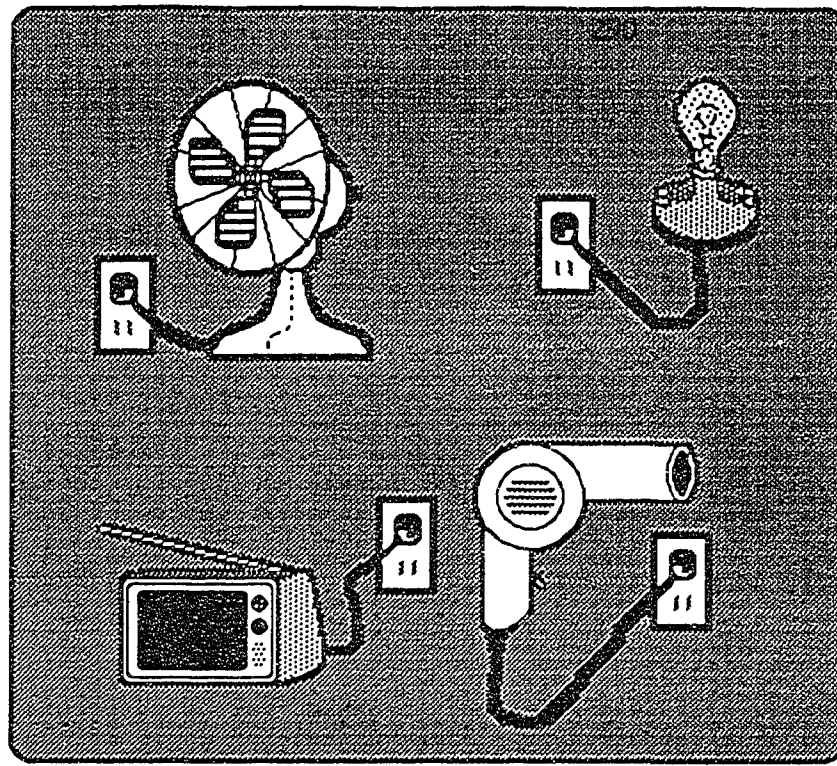
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◀ Go Back | Go On ▶



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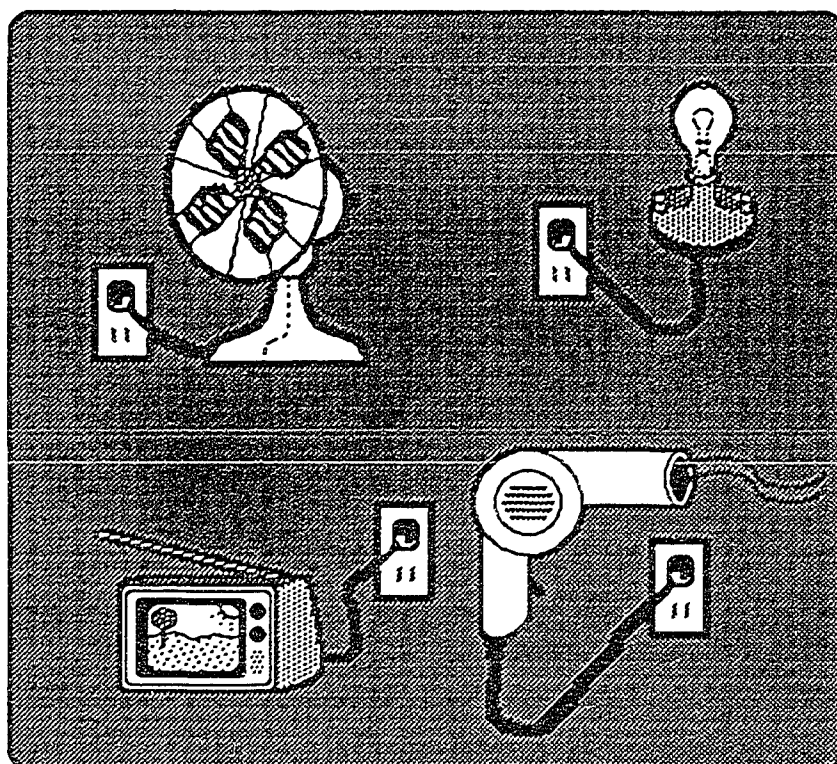
◀ Go Back | Go On ▶



You probably use electricity everyday to light a room, cool dry your hair, or make popcorn in a microwave oven. Twist a knob or push a button, and a radio or television set begins to play. Flip a switch, and a fan is turned on. Each of these appliances work by using electrical energy via circuits.

Do you know how electricity causes appliances to work?

Go Back Go On

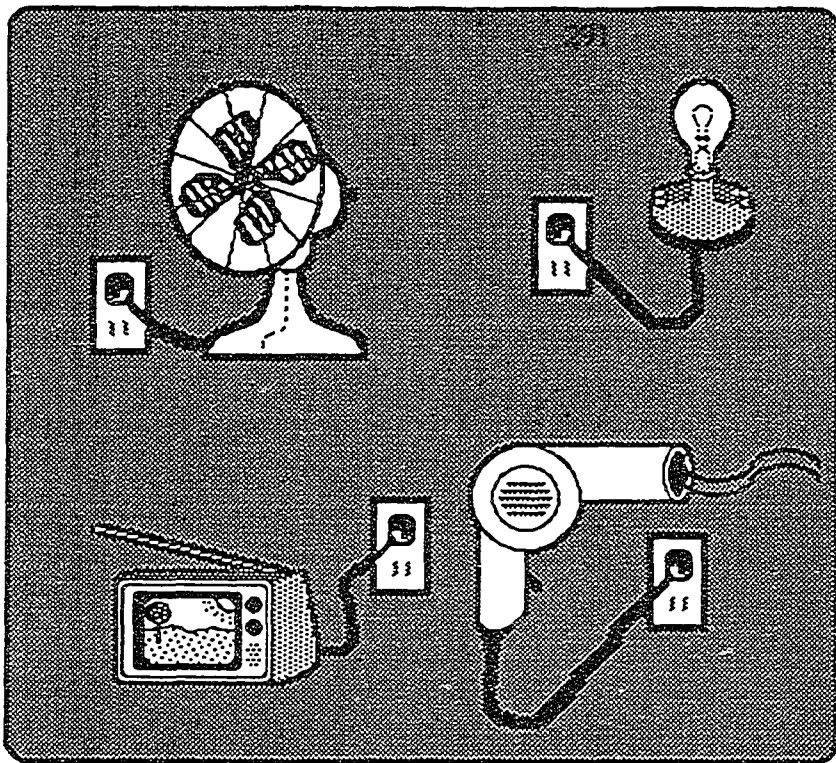


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Go Back Go On





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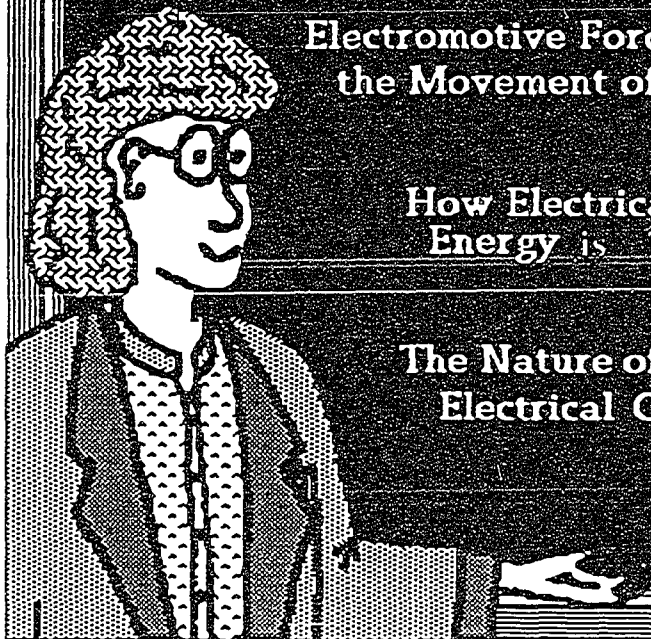
[Go Back](#) [Go On](#)

## Overview of Electrical Energy: Current & Circuits

Electromotive Force &  
the Movement of Electrons

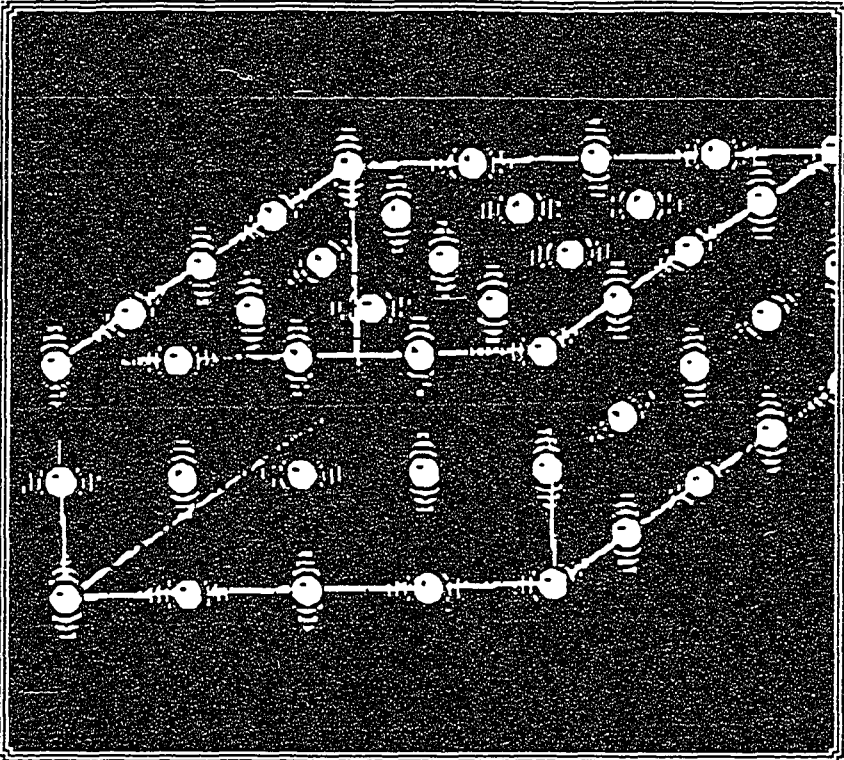
How Electrical  
Energy is Transferred

The Nature of  
Electrical Circuits



You will find out by studying the information in this stack where we will examine electrical energy, electric circuits, and measuring electrical parameters.

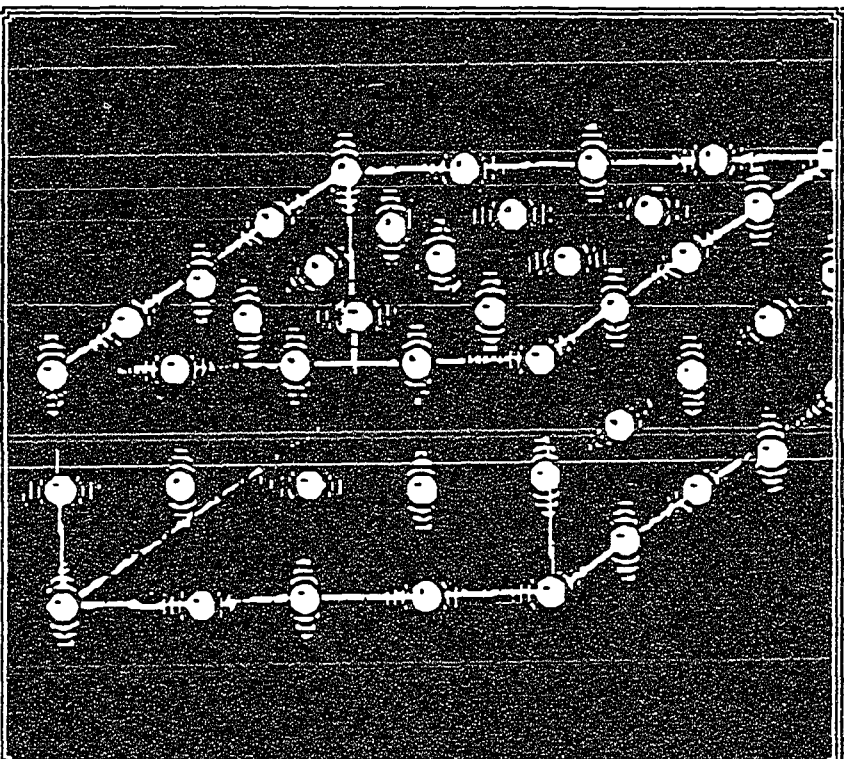
[Go Back](#) [Go On](#)



What is electrical energy?

To answer this question it is necessary to review some basic concepts about matter. As you may recall from previous science lessons, all matter is composed of atoms.

Go Back Go On



What is electrical energy?

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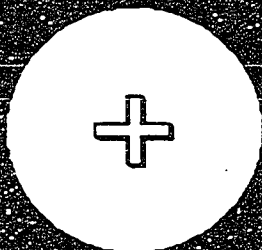
Go Back Go On



Proton  
Neutron

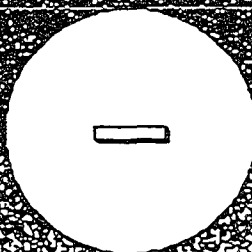
In turn, atoms are made up of subatomic particles which include protons, electrons, and neutrons. Protons and neutrons are found in the nucleus or center of an atom and account for most of the mass of an atom. Whirling around the nucleus are electrons.

Go Back Go On



***Proton***

***Electron***



Protons and electrons possess electric charges. Protons are positively charged particles (+) and electrons are negatively charged particles (-).

Electrical energy arises from the interactions among these charged particles.

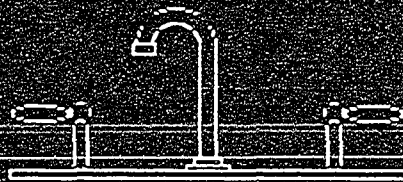
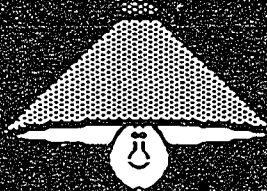
Go Back Go On



Particles with the same charges repel each other with increasing strength as they come closer together, and particles of different charges attract each other with increasing strength as they come closer together. This concept of how electrons and protons react to each other is the basis upon which electrical charges move to make electric appliances operate.

Go Back Go On

OFF

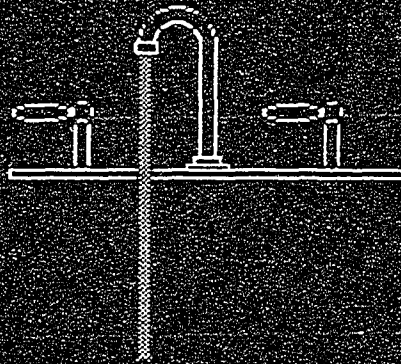
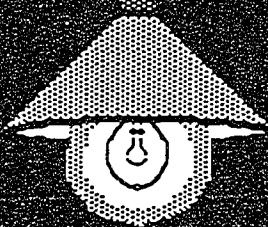


### Introduction to How Electrical Energy is Transferred:

What do switching on a light and turning on a faucet have in common? Opening the faucet lets water flow through a pipe. Turning on an electric light switch permits **electrons** to flow through the wires. However, water will not flow through the pipe unless a **force** is present to move it.

Go Back Go On

ON

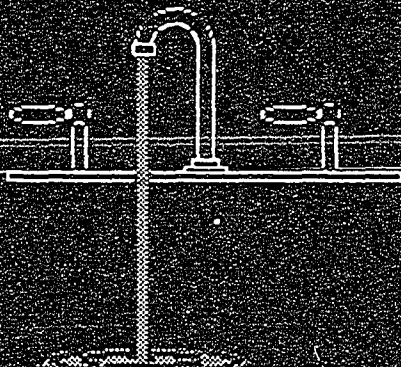
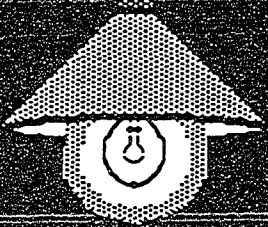


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Go Back Go On

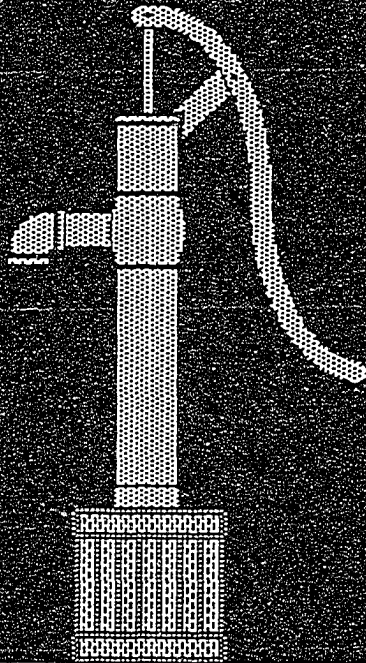
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### Introduction to How Electrical Energy is Transferred:

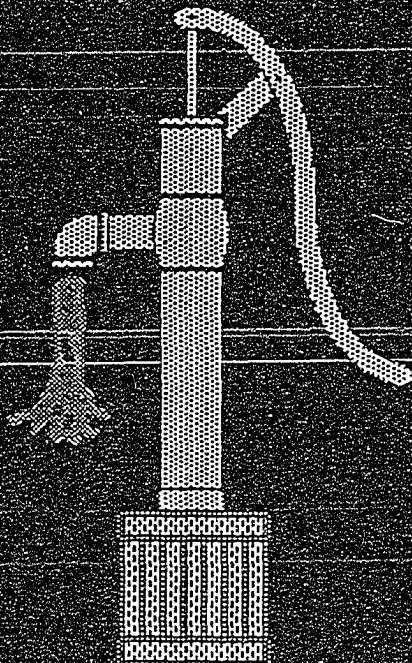
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Go Back Go On



That force could be supplied by gravity causing the water to flow down hill or a pump could supply the force needed to move the water. Similarly, electrons flowing through a conductor also need a force to cause them to move.

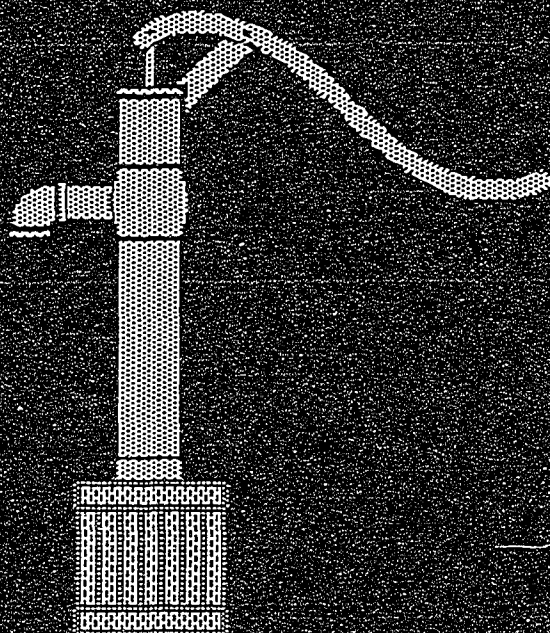
Go Back Go On



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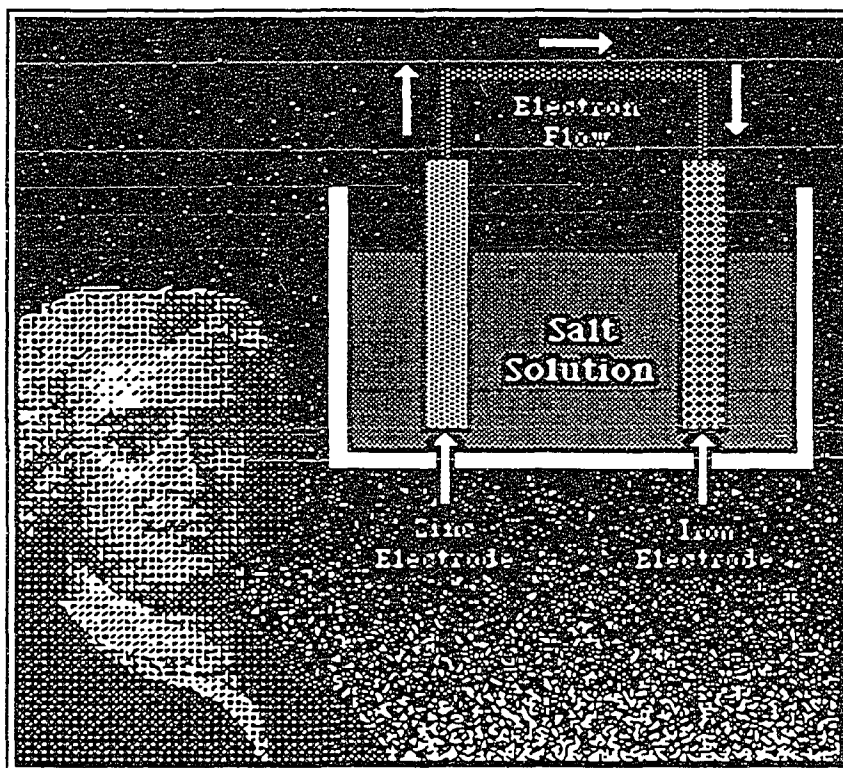
Go Back Go On





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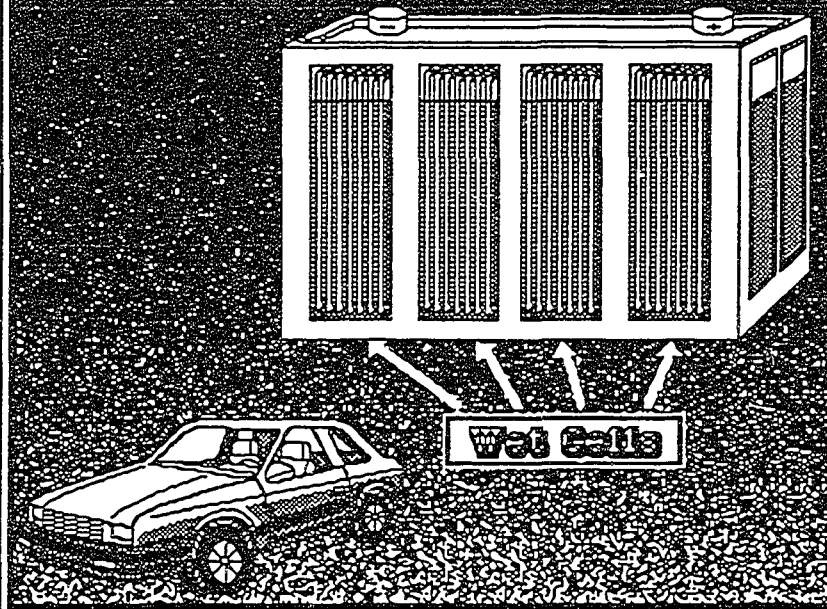
Go Back Go On



Around 1800, an Italian scientist named Alessandro Volta discovered a way to make **electrons** move through a **conductor**. Volta found that when the metals iron and zinc were placed with a salt water solution a chemical reaction occurred: the chemical reaction between the metals and the salt solution caused the electrons to move. This arrangement of iron and zinc metals and salt solution is called an **electrochemical cell**.

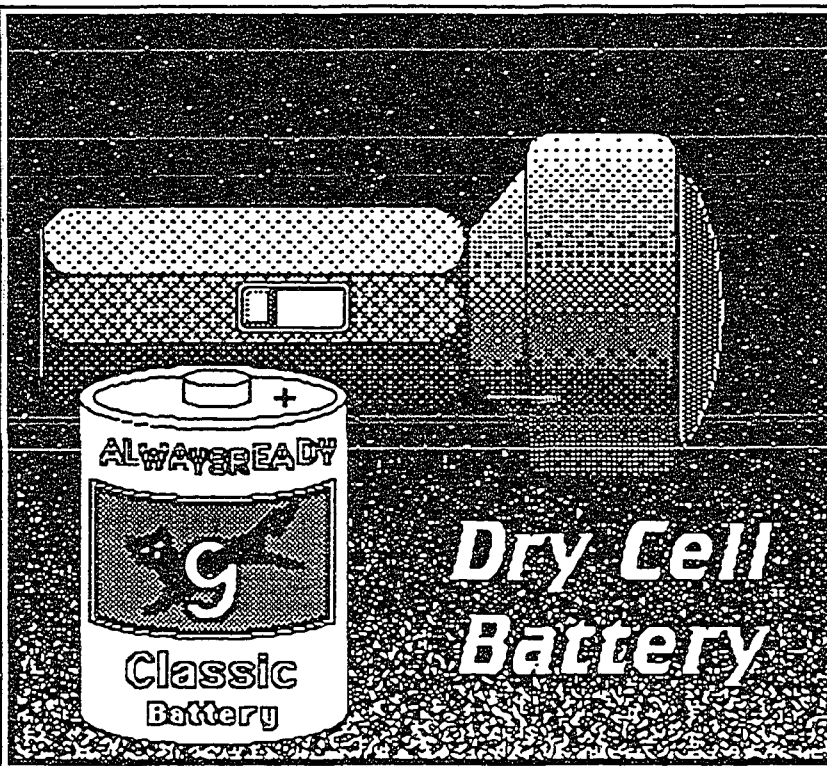
Go Back Go On

## ***Car Battery with Wet Cells***



An automobile battery is made up of several electrochemical cells. Inside of the battery an electrochemical cell stores energy that can cause electrons to move and thus create electrical energy.

Go Back Go On



An ordinary flashlight battery is also a kind of electrochemical cell. It is often called a dry cell because it does not contain a liquid form of the salt solution. Instead, a moist chemical mixture is used.

Go Back Go On





## Dry Cell Battery

An ordinary flashlight battery is also a kind of electrochemical cell. It is often called a dry cell because it does not contain a liquid form of the salt solution. Instead, a moist chemical mixture is used.

Go Back Go On



Energy Transfer Path



Streets & Avenues



In order for electrical devices to operate, electrical energy must be transferred from the battery to the device. Just like streets and avenues route people to specific locations within a city, an electric circuit transfers electrical energy (carried by electrical charges) to appliances. The rate at which electrons move through a circuit is called **current**.

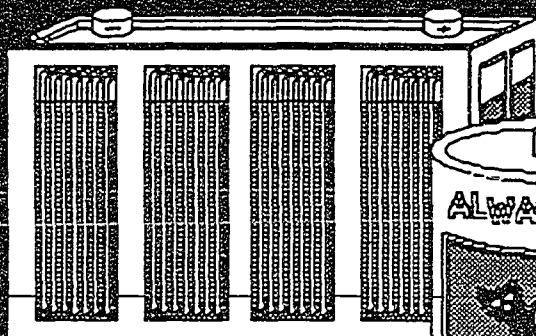
Go Back Go On



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Go Back Go On

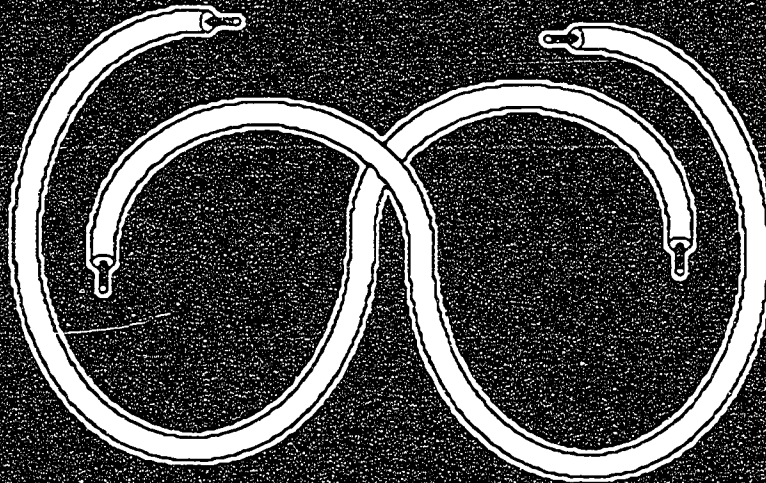
## Power Source



An electrical circuit is made of a power source and wires that can transfer the electrical energy stored in the power source. In addition, most circuits include a device or appliance which needs electrical energy to operate.

Go Back Go On

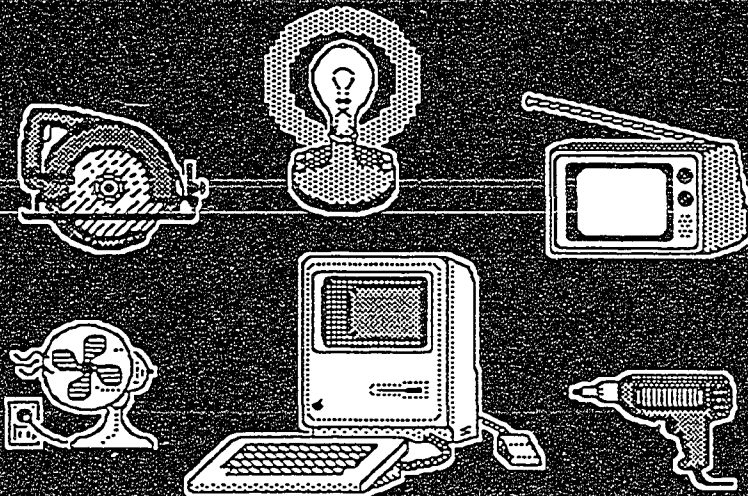
# Wires



An electrical circuit is made of a power source and wires that can transfer the electrical energy stored in the power source. In addition, most circuits include a device or appliance which needs electrical energy to operate.

Go Back Go On

# Appliances



An electrical circuit is made of a power source and wires that can transfer the electrical energy stored in the power source. In addition, most circuits include a device or appliance which needs electrical energy to operate.

Go Back Go On

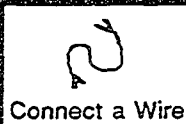
## Battery

The battery may be moved around the screen by holding down the mouse button while moving the mouse.



## Bulb

The bulb may be moved around the screen by holding down the mouse button while moving the mouse.



Connect a Wire

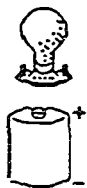
## Wires

Click on this button to begin to connect both ends of the wires.

Describe how you think a circuit must be constructed and how electrical energy flows through the circuit to make the bulb light.

Shown here is a battery, bulb, and wires as well as instructions on how to use each item. After reading these instructions click the Go On button.

Go Back Go On



BACK TO INSTRUCTIONS



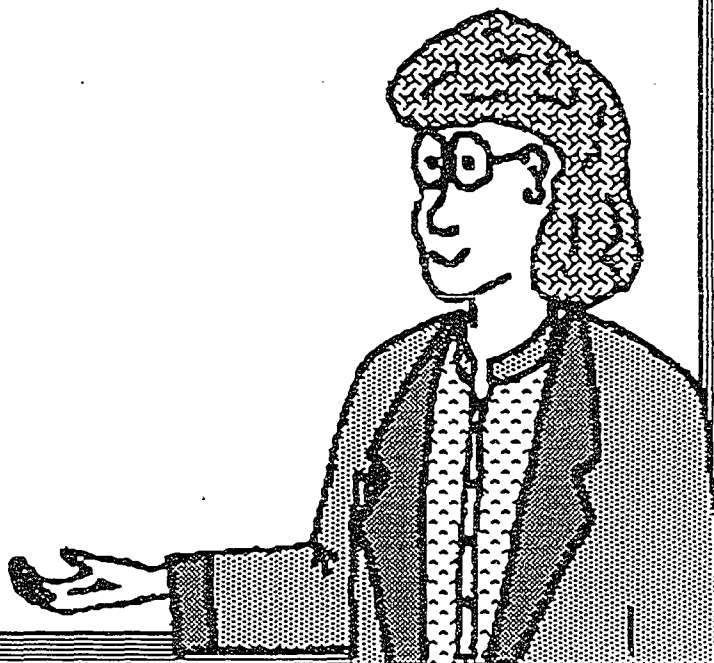
Connect a Wire



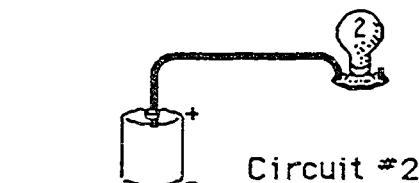
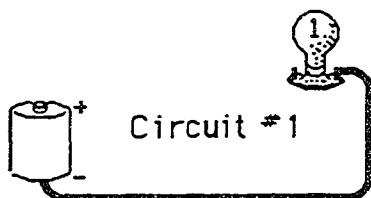
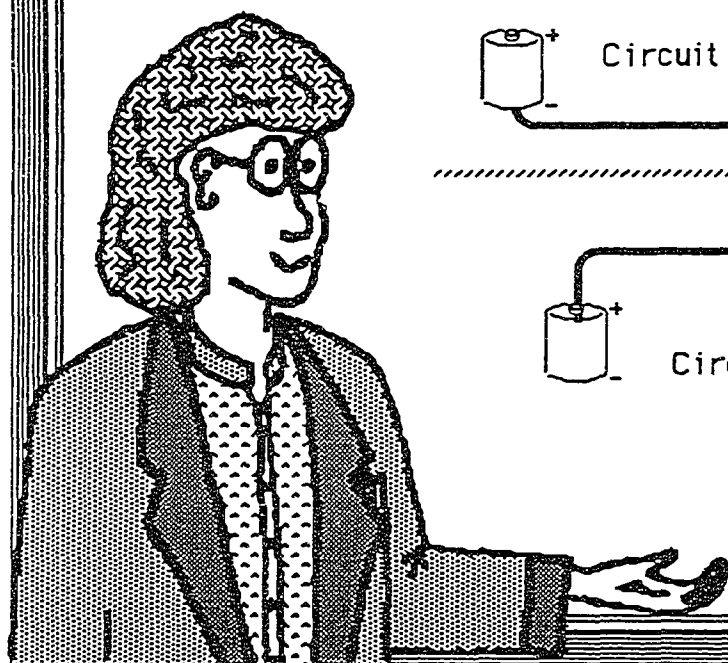
Disconnect Wires



Done





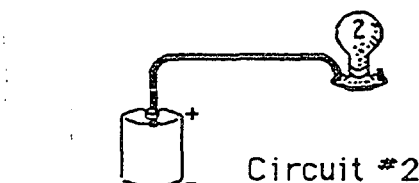
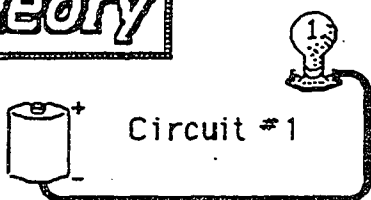
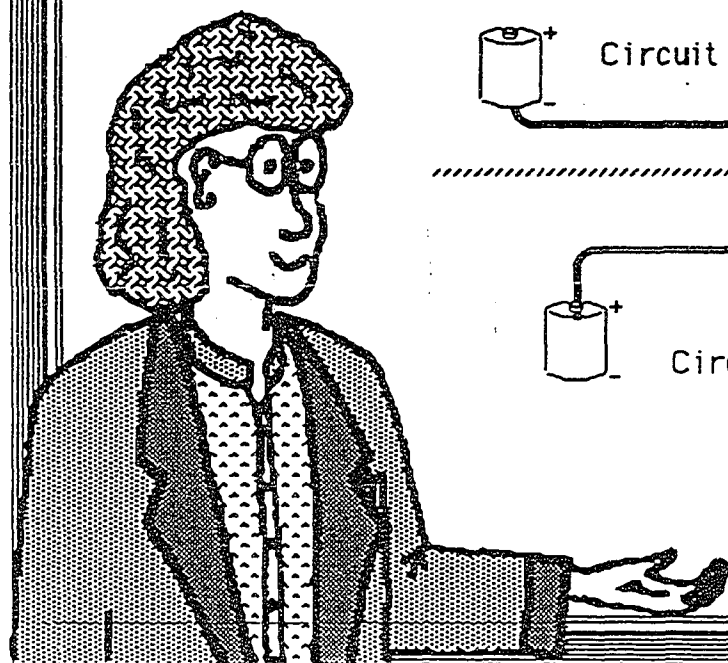


Different students give a number of different answers to how a circuit can be constructed to cause the bulb to light.

Some students believe that a single wire between the battery and the bulb will cause the bulb to light. They think that bulb #1 and #2 will light.

Go Back Go On

## The Sink Theory



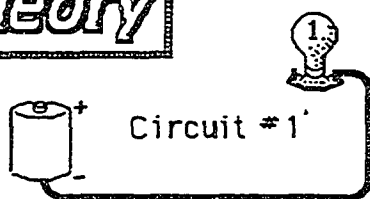
This view is called the Sink Theory. The Sink Theory states that electricity can leave a power source, travel to an electrical device via a single conducting wire, and not return to the battery.

Do you think these students are correct?

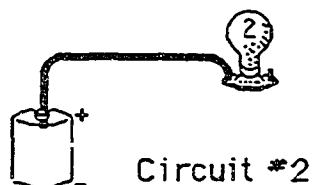
Will circuit #1 cause the bulb to light? Describe how the electrical energy in circuit 1 flows to justify your answer.

Go Back Go On

# *The Sink Theory*



////////////////////////////////////

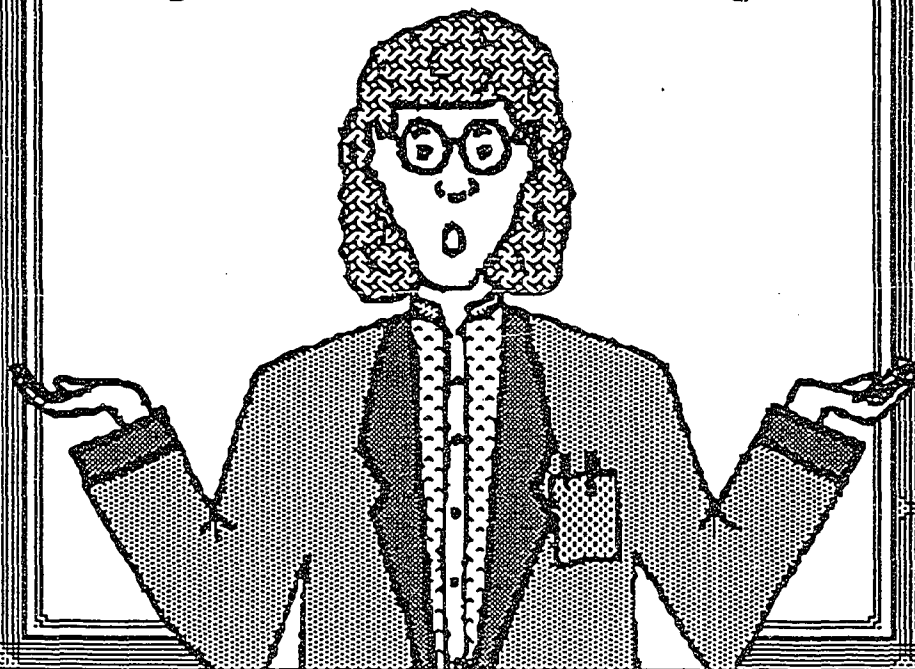


Will circuit #2 cause the bulb to light? Describe how the electrical energy in circuit #2 flows to justify your answer.

What is the difference between circuit #1 and #2?

Go Back Go On

# ~~*The Sink Theory*~~



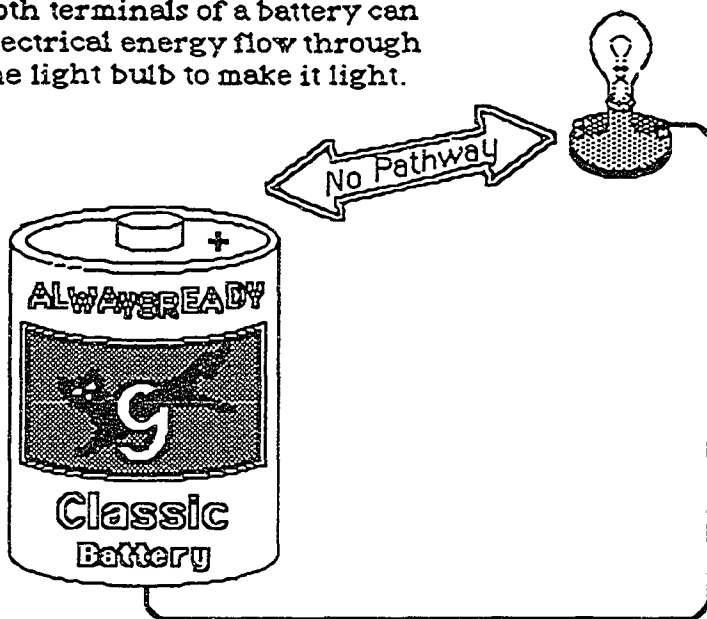
Students who believe the Sink Theory are incorrect.

The Sink Theory is wrong.

How can we illustrate that the Sink Theory is incorrect?

Go Back Go On

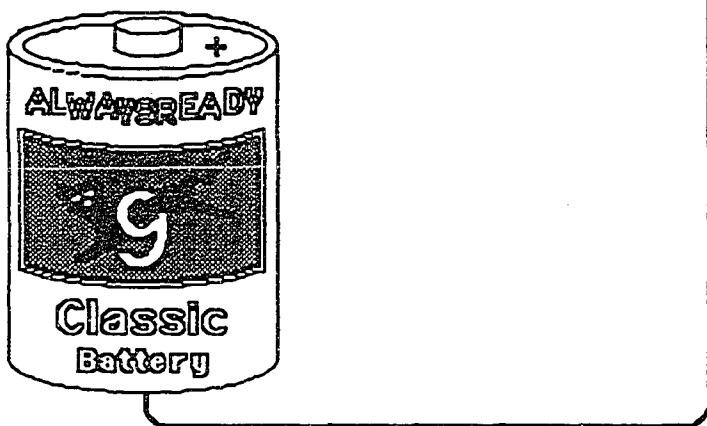
Only when a bulb is connected to both terminals of a battery can electrical energy flow through the light bulb to make it light.



Once the negative terminal of the battery is connected with a wire to the bulb, electrons can move from the battery to the bulb, but if another wire is not connected from the bulb to the positive terminal of the battery, the electrons will have no path to leave the bulb.

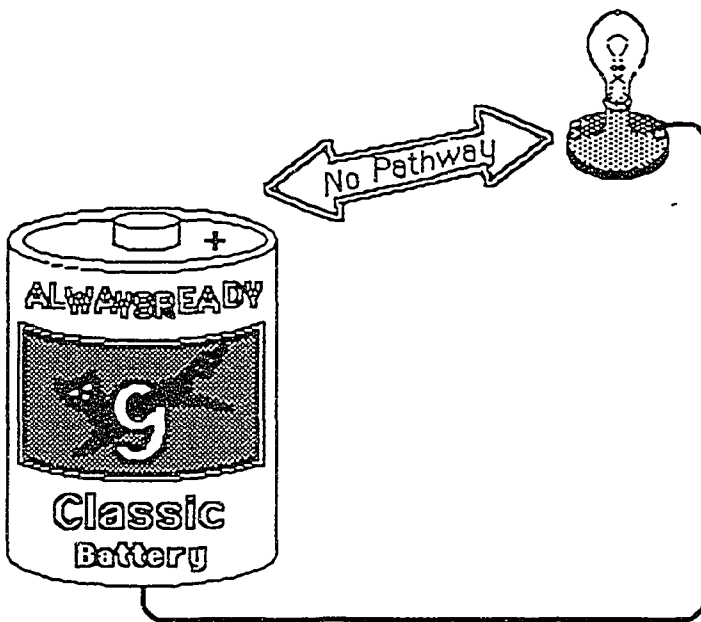
Go Back Go On

Only when a bulb is connected to both terminals of a battery can electrical energy flow through the light bulb to make it light.



The electrons which moved toward the bulb are negatively charged. When some reach the bulb they will repel and prevent any further electrons from reaching the bulb, so the flow of electrons stops almost instantly. Now, when a wire is connected between the positive terminal of the battery and the bulb, the electrons can continue moving. They are attracted to the positive terminal and the flow of electrons can be maintained.

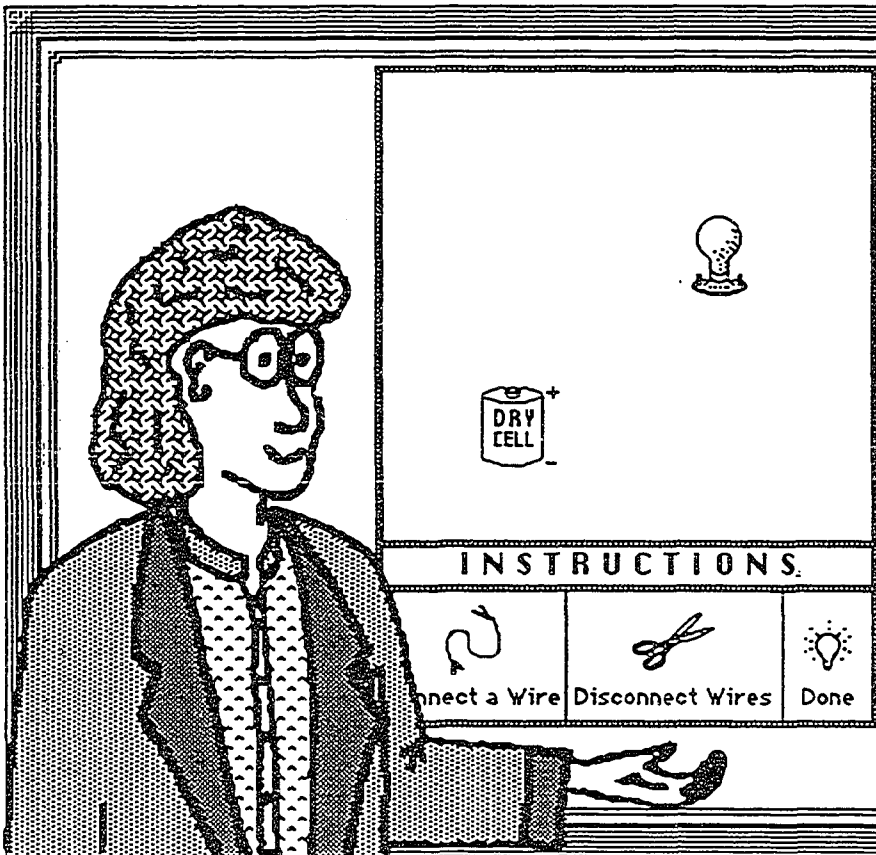
Go Back Go On



Only when a bulb is connected to both terminals of a battery can electrical energy flow through the light bulb to make it light.

In the Sink Theory there is one wire connecting a battery terminal and an electrical device. There is no path between the battery terminals and the device to allow the electrons to move through the device; therefore, it is not possible to maintain a flow of electrons which is required for the bulb to light.

Go Back Go On



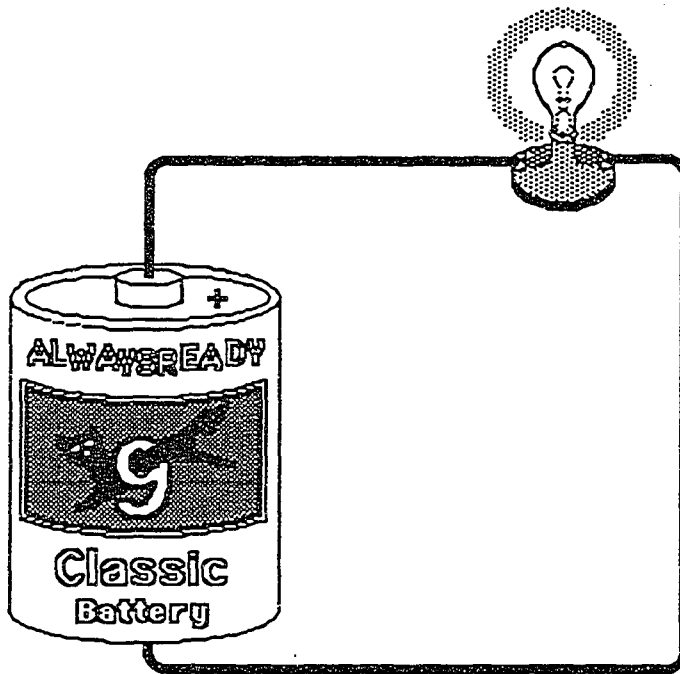
At this point you will return to our experiment to use what we have just learned.

You will use the same equipment you used before to try to get the bulb to light.

Click the **Go On** button to begin the experiment.

Go Back Go On

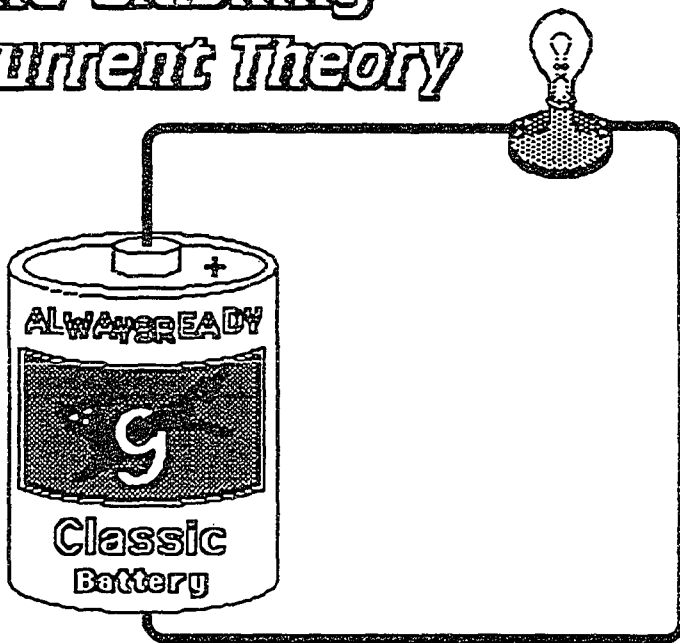




Many students know that two wires or pathways are needed to make the bulb light—one from the power source to the device and another from the device to the power source.

Go Back Go On

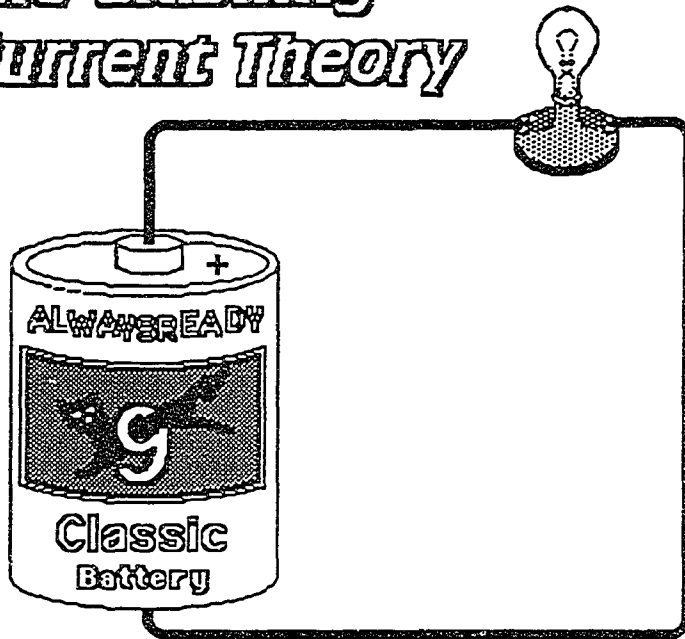
## *The Clashing Current Theory*



Many students know that two wires or pathways are needed to make the bulb light—one from the power source to the device and another from the device to the power source.

Go Back Go On

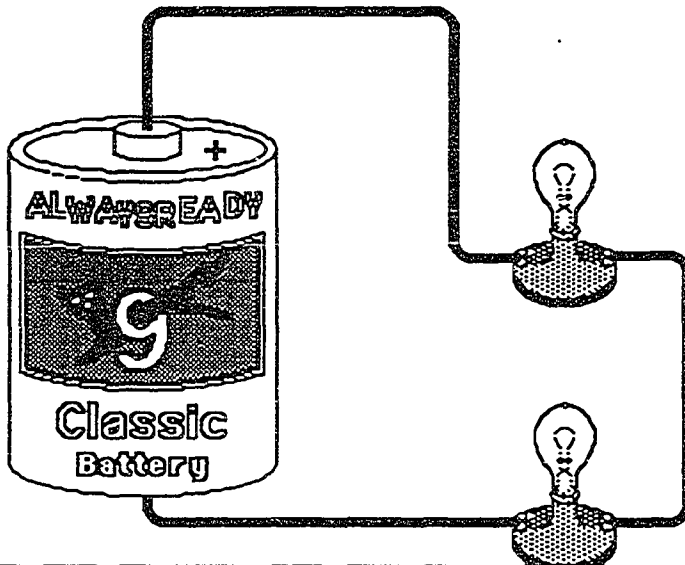
## The Clashing Current Theory



Clashing Current Theory states that because the battery terminals have opposite charges, electricity flows in two directions in an electrical circuit and meets at the device. The conflict of positive and negative electrical charges causes the bulb to light.

Go Back Go On

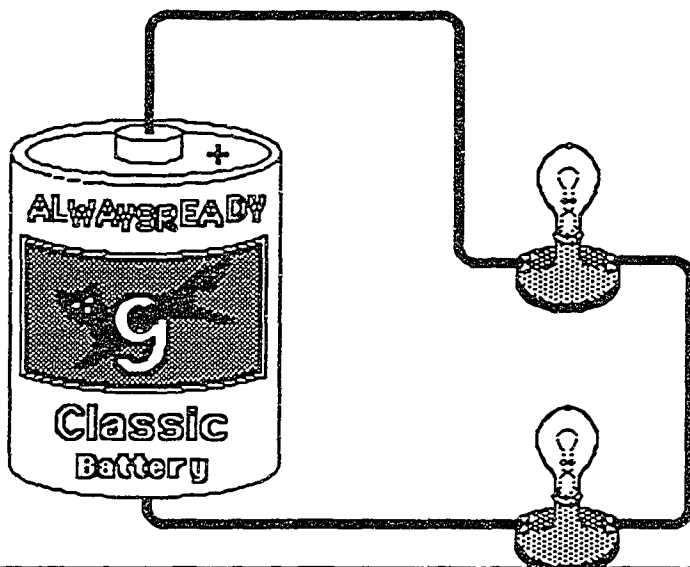
## The Clashing Current Theory



Are students who accept the Clashing Current Theory correct? In the circuit shown here, there are two light bulbs at different locations within the circuit. Will this circuit cause both bulbs to light? Describe how the electrical energy in this circuit flows to justify your answer.

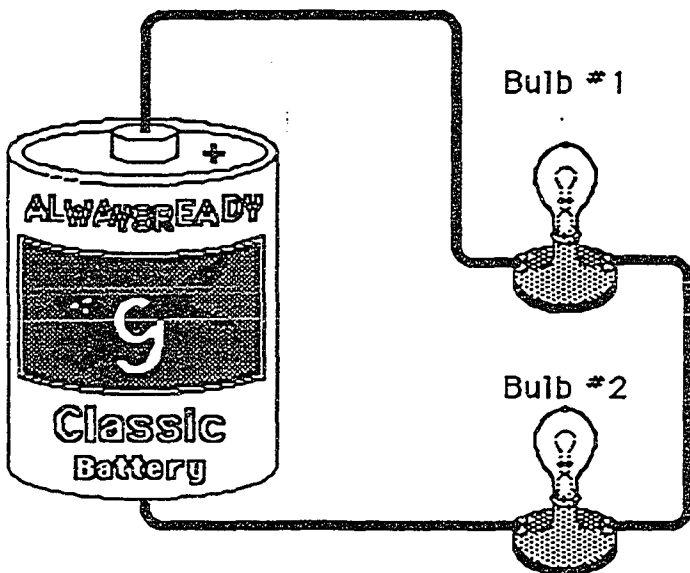
Go Back Go On

~~The Clashing  
Current Theory~~



Students who think that the Clashing Current Theory is right are incorrect. The Clashing Current Theory is wrong. How can we illustrate that this theory is wrong?

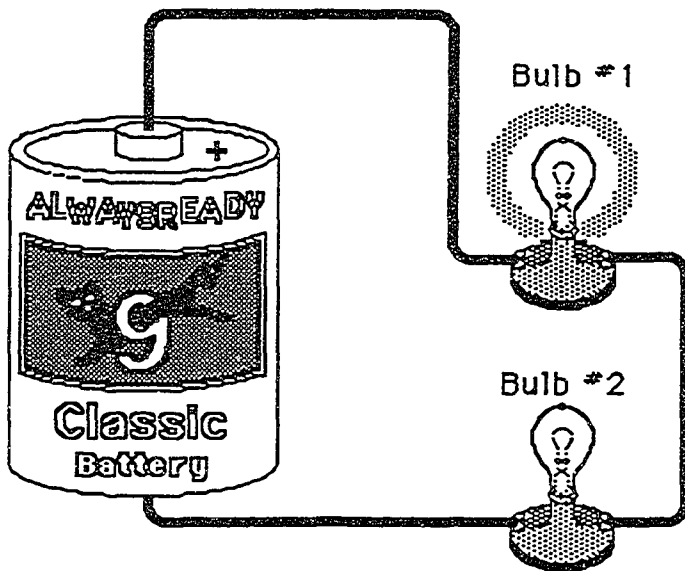
Go Back Go On



Let's examine this circuit with reference to the Clashing Current Theory. According to the Clashing Current Theory, positively charged electrical energy flows through the circuit only until it meets negatively charged electrical energy. In the same way, negatively charged electrical energy flows through the circuit only until it meets positively charged electrical energy.

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Thus, according to the Clashing Current Theory, bulb #1 would light but bulb #2 would not light because bulb #1 has both positive and negative electricity clashing while bulb #2 has only negative electricity passing through it.

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Here is your chance to test the Clashing Current Theory.

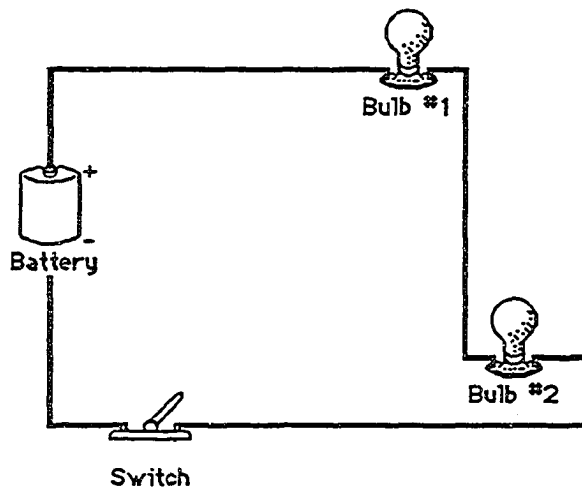
Simply click the "Test" button and a new circuit will be constructed for you.

If only one bulb lights, then the Clashing Current Theory is correct.

However, if both bulbs light then this theory is incorrect.

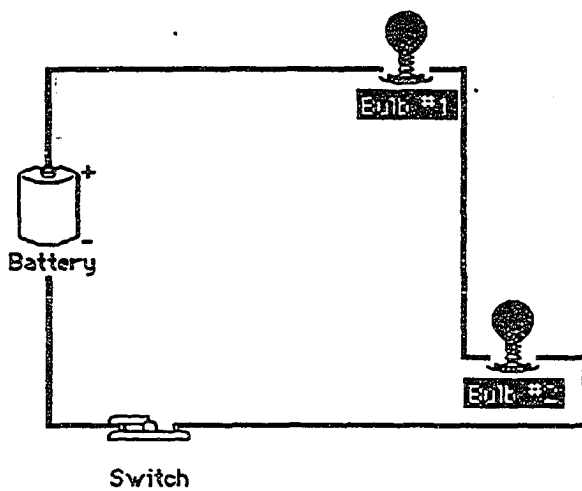


Test



When you constructed and tested the circuit, you found that both bulbs lit. This proves that the Circling Current Theory is wrong. Electrical energy does not flow in opposite directions from both the positive terminal and the negative terminal of the battery simultaneously and meet at the electrical device. Current in a circuit moves in one direction from one terminal of a battery to the other.

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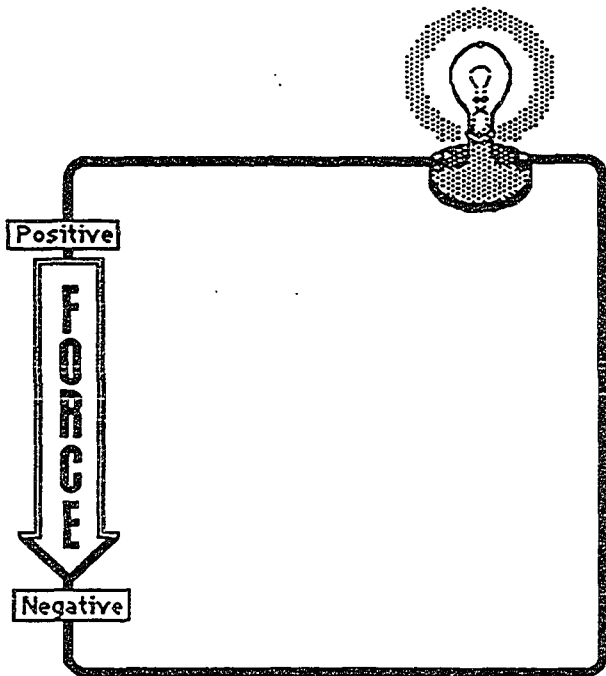


When you constructed and tested the circuit, you found that both bulbs lit. This proves that the Circling Current Theory is wrong. Electrical energy does not flow in opposite directions from both the positive terminal and the negative terminal of the battery simultaneously and meet at the electrical device. Current in a circuit moves in one direction from one terminal of a battery to the other.

Go Back Go On

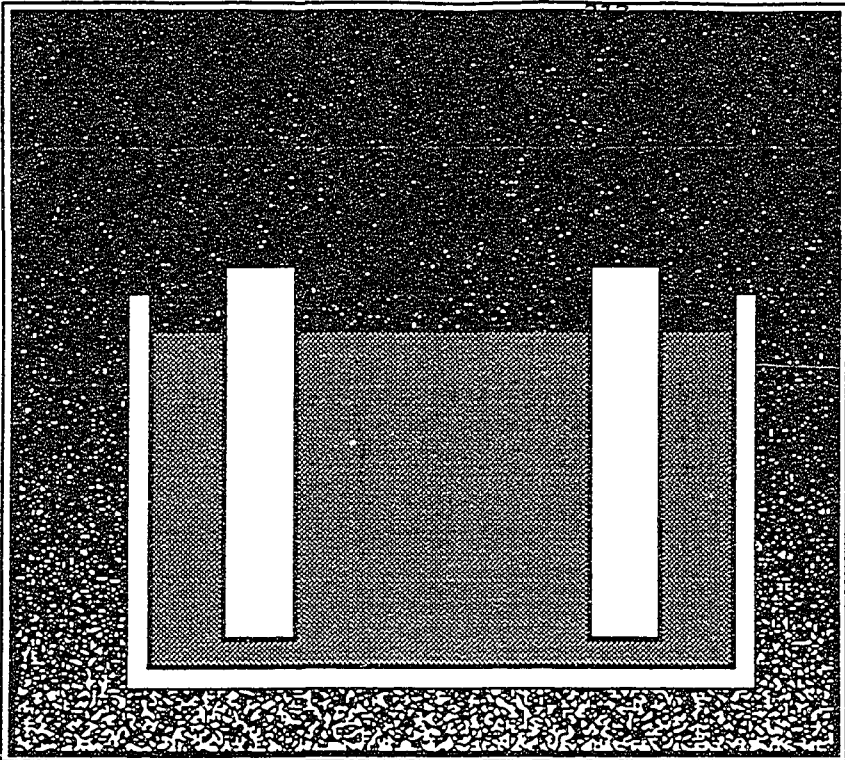
# THE NATURE OF ELECTRIC CIRCUITS

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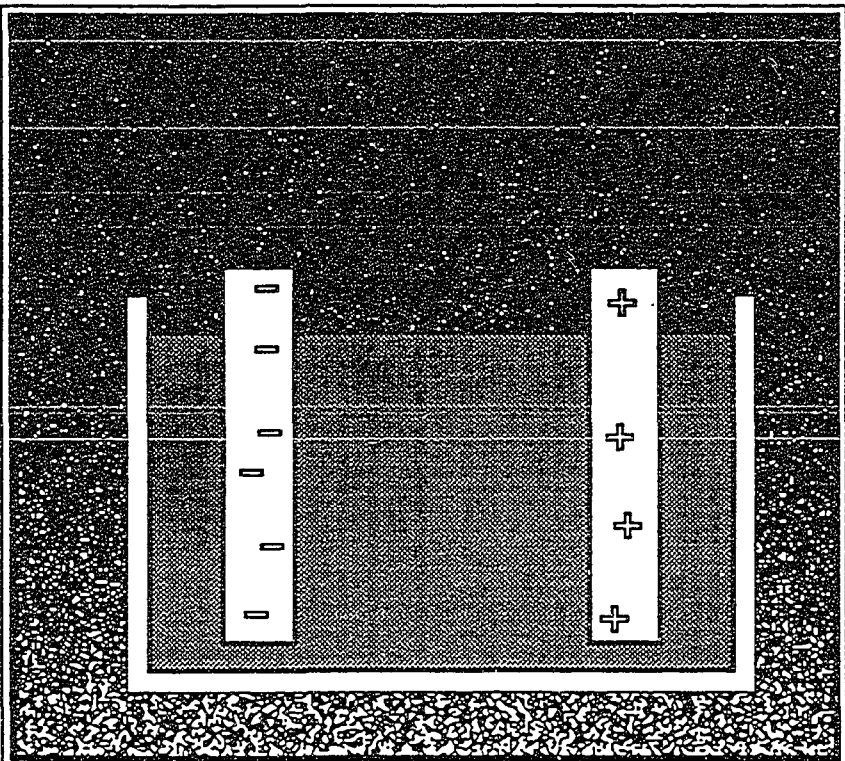
Go Back Go On





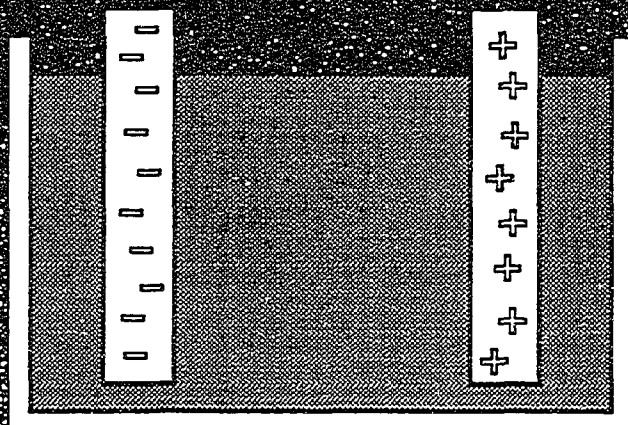
The force needed to move electrons is created by chemical changes taking place within the electrochemical cell of a battery. These chemical changes cause the negative terminal (-) to produce a surplus of electrons. Also because of the chemical changes, the positive terminal (+) of the cell lacks a normal supply of electrons.

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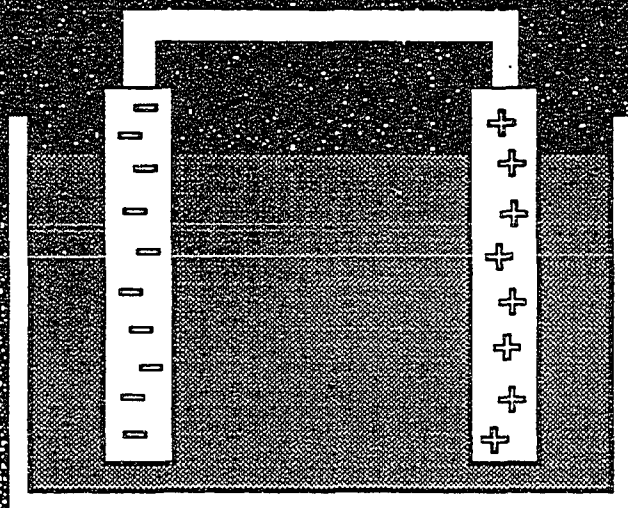
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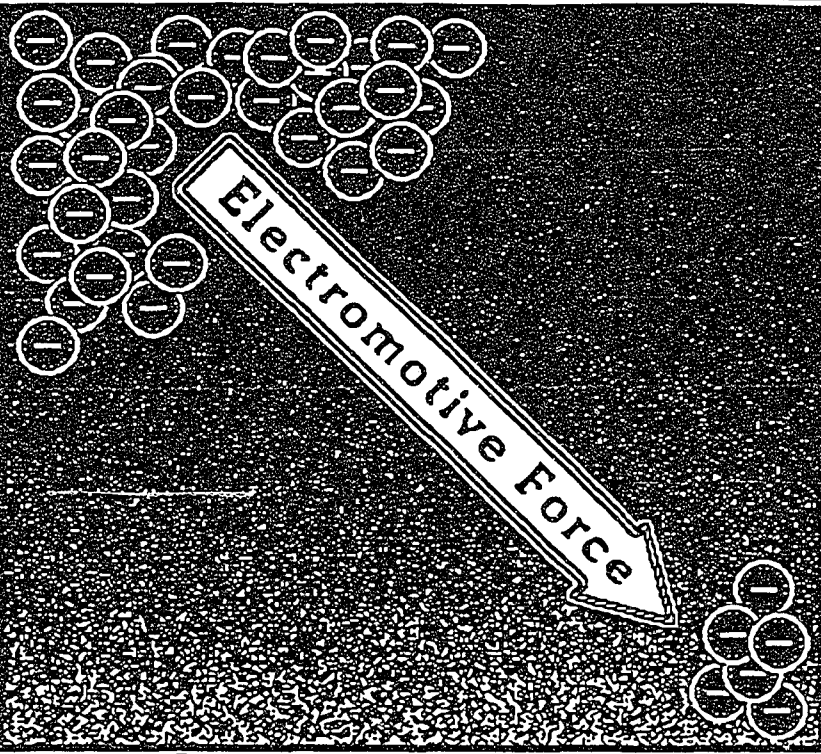
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If wires that are capable of conducting electrical energy are attached to the positive and negative terminals of the battery the surplus of electrons in the negative terminal have a path to the positive terminal which has a shortage of electrons. This movement of electrical charges is called current.

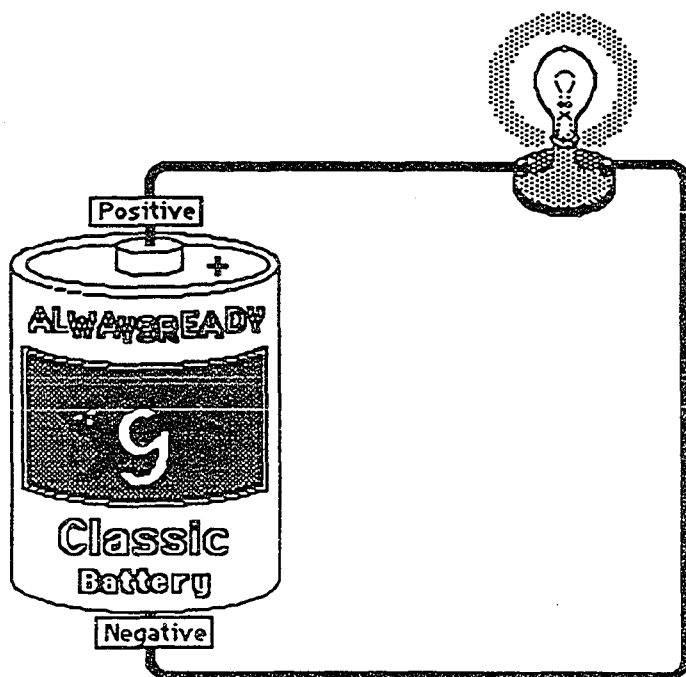
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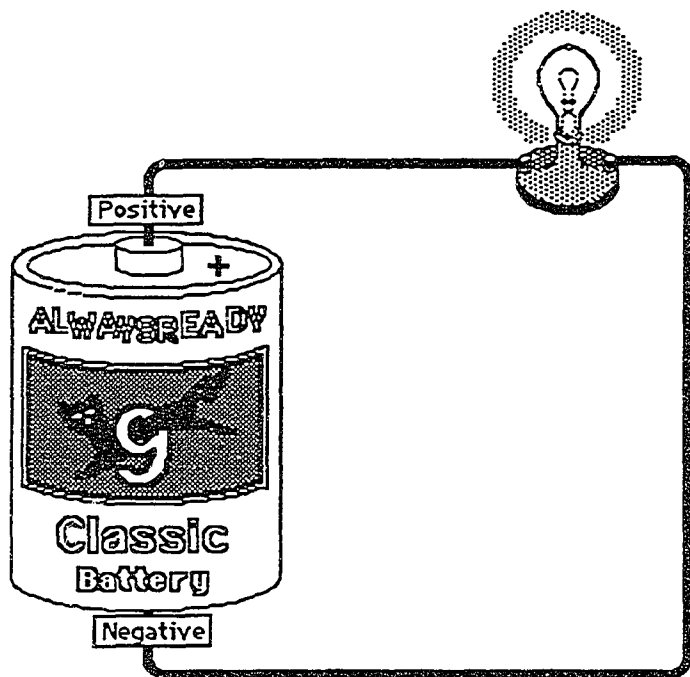
Because of the difference in the numbers of electrons in the terminals, an electric potential difference exists between the terminals. This is called the **electromotive force**. It is this force that causes electrons to move in a circuit.

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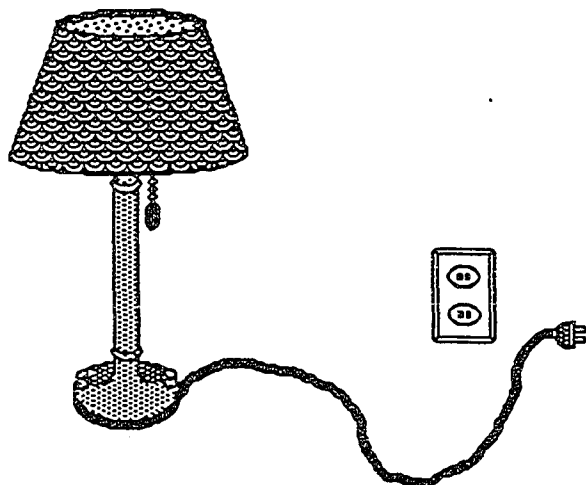
When the negative and positive terminals of a battery are connected by a wire, a complete circuit is formed. This allows electrons to flow from the negative terminal to the positive terminal, creating an electric current.

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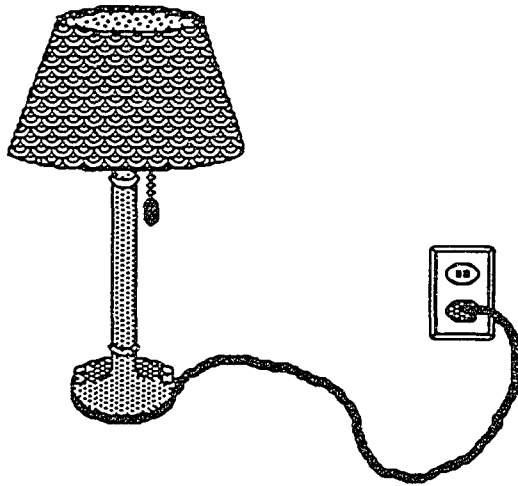
In this illustration, electrical energy is supplied to the light bulb through the circuit. Notice a wire connects the negative battery terminal and the light bulb, and another wire connects the light bulb and the positive battery terminal, thus creating a complete path in which electric current can flow.

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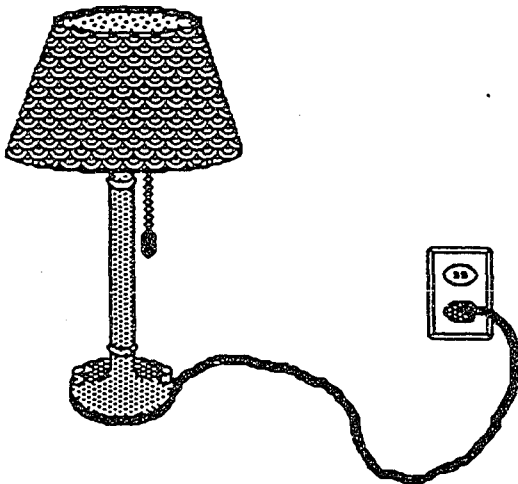
When you plug a lamp into an electric outlet and turn on the switch, you are completing an electric circuit. The two parts of the plug and the pair of wires within the cord provide a complete circuit, an electric current can then flow through the lamp that is plugged into the outlet and produce light.

Go Back Go On



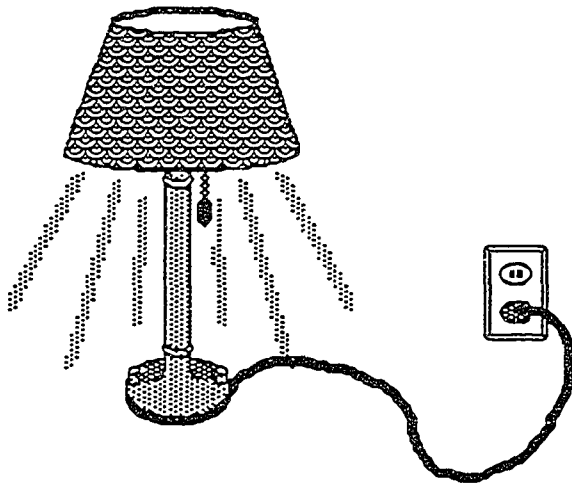
When you plug a lamp into an electric outlet and turn on the switch, you are completing an electric circuit. The two parts of the plug and the pair of wires within the cord provide a complete circuit; an electric **current** can then flow through the lamp that is plugged into the outlet and produce light.

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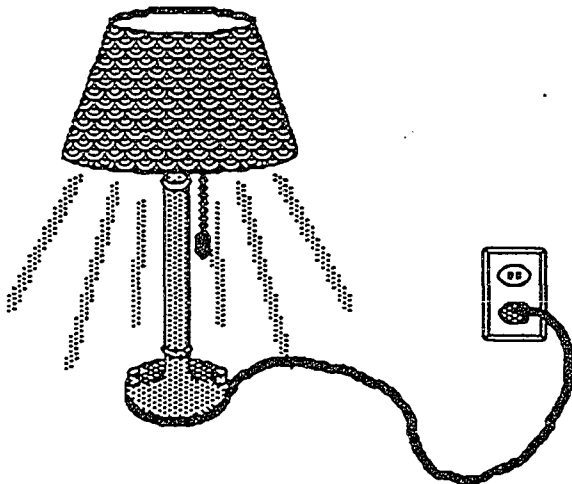
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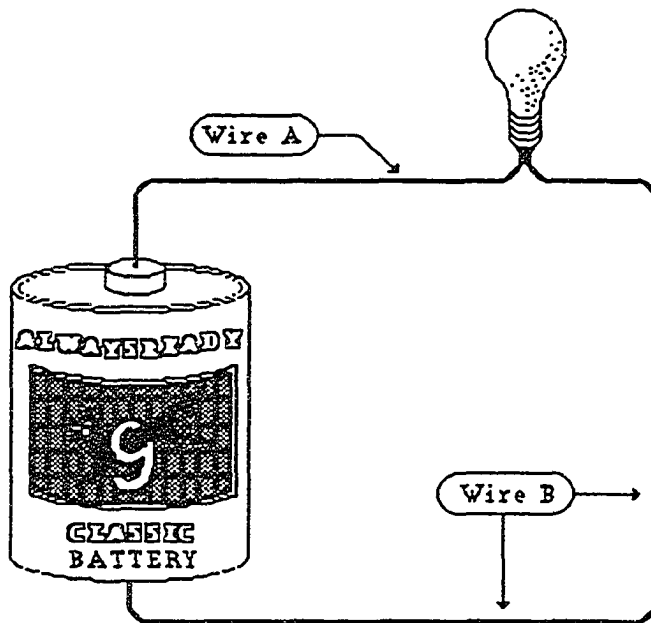
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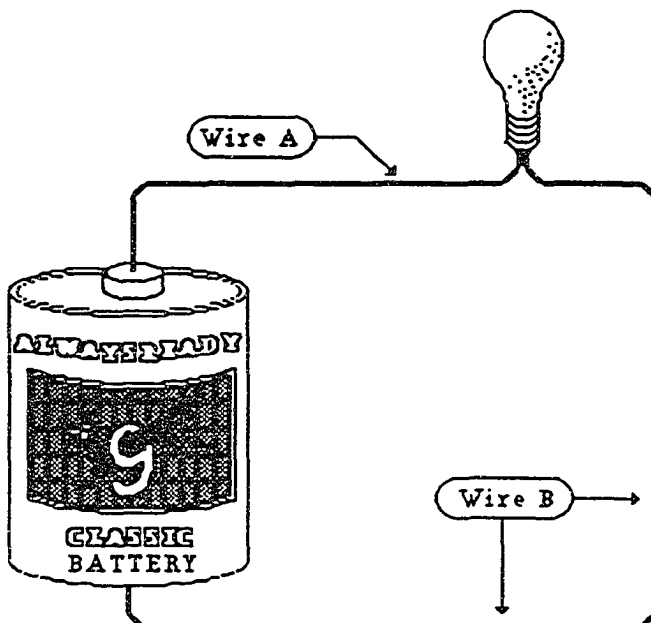
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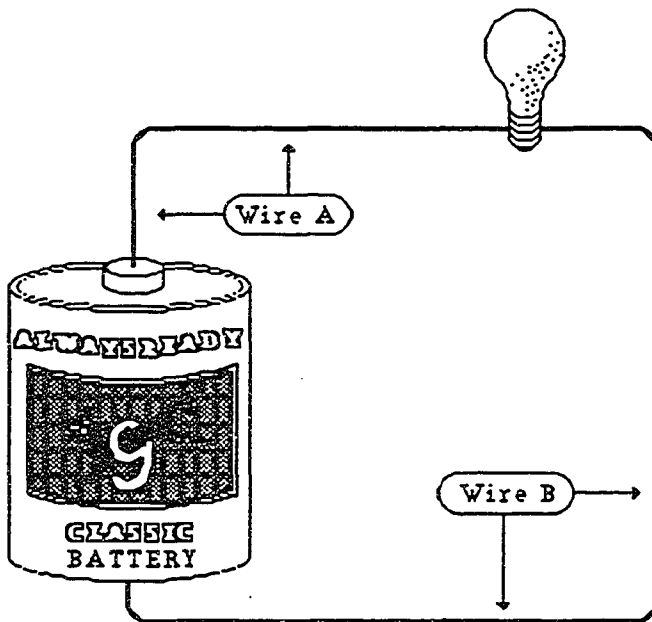


Given what you have learned about electric circuits, do you think that the light bulb in this illustration will light?

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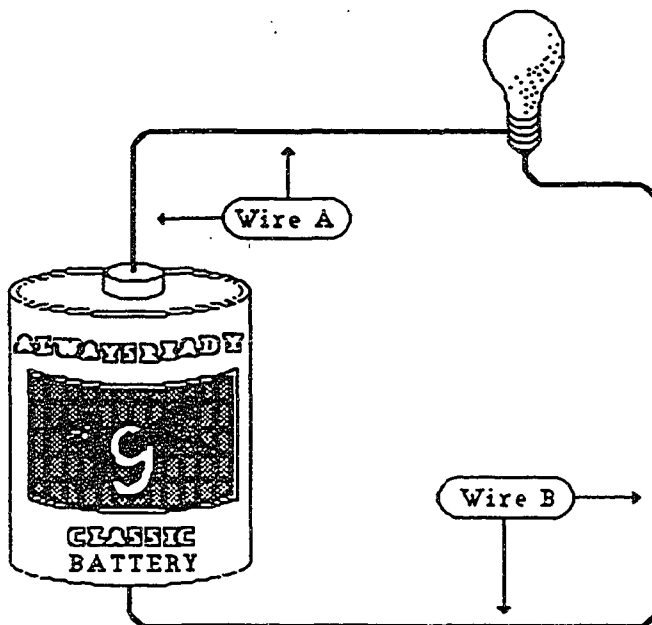


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In this illustration both wires A and B are connected to the sides of the bulb. The bulb will not light because the wires are both attached to the same electrical connection, so current is not able to pass through the bulb.

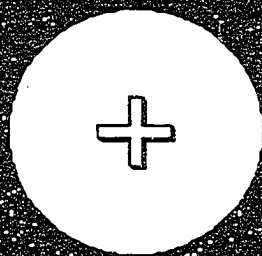
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In this illustration wire A is attached to the side of the bulb (an electrical connection) and wire B is connected to the bottom of the bulb (the other electrical connection). The bulb lights because electric current is able to pass through the bulb.

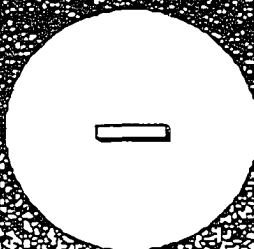
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***Proton***

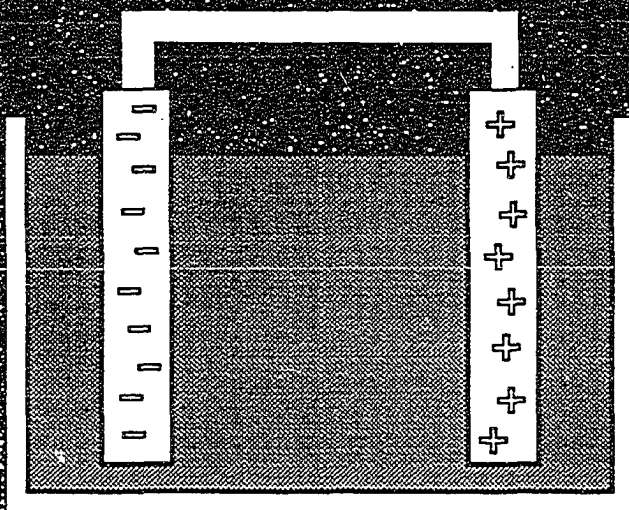
***Electron***



## REVIEW

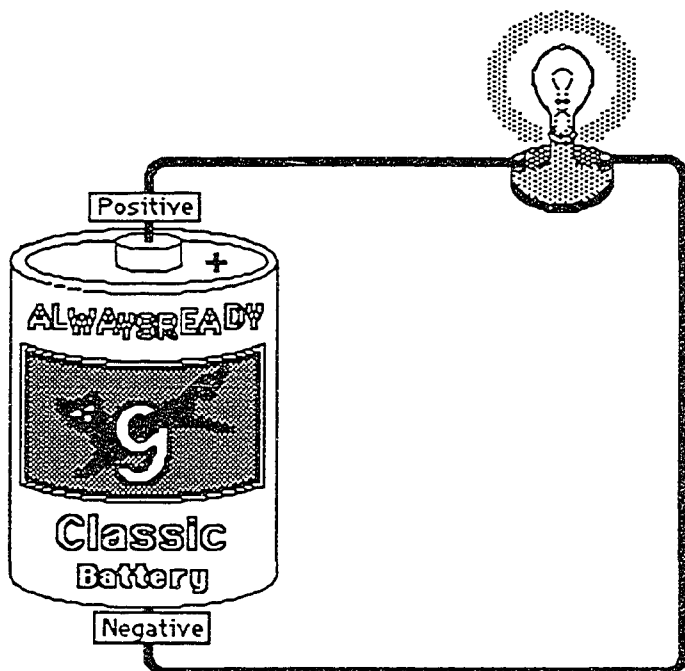
Let's review what you have learned about electrical energy and circuits thus far. As you may recall, electrons and protons are electrically charged particles of an atom. An electron is a negatively charged particle and a proton is a positively charged particle.

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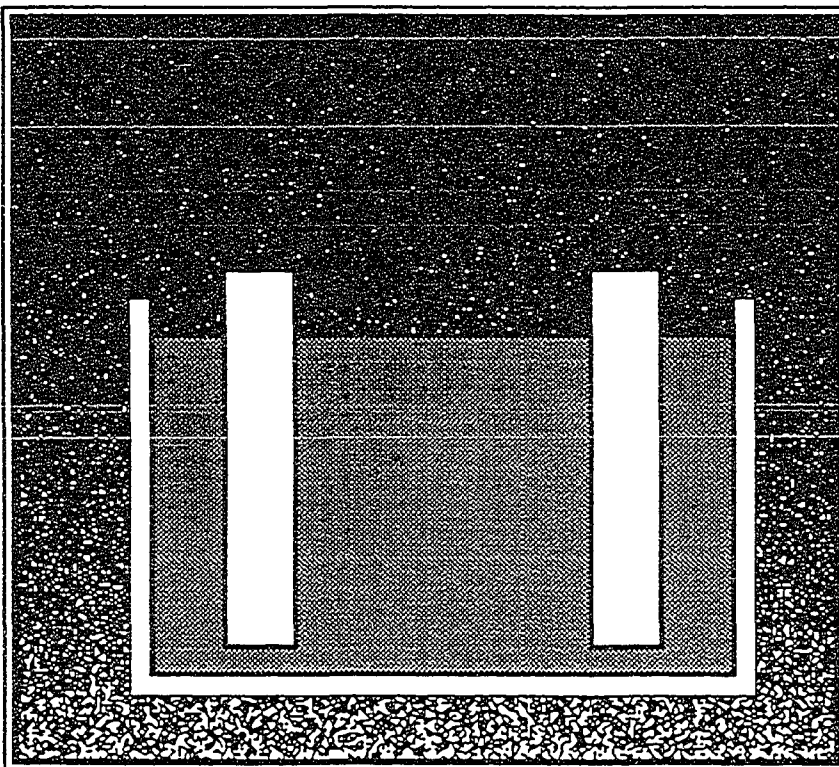
To generate electrical energy, a mechanism must cause the electrons to move. An electrochemical cell produces a chemical reaction that causes electrons to move within a circuit. An electric circuit is a complete path between negative and positive terminals of a power source that allows electrons to move and create a flow of electrical charges. The rate at which electrons move through a circuit is the current.

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Although electrons do not actually move a great distance within a conductor, the repelling action they produce causes electrical charges to flow through the conductor, which transfers electrical energy to devices causing them to work.

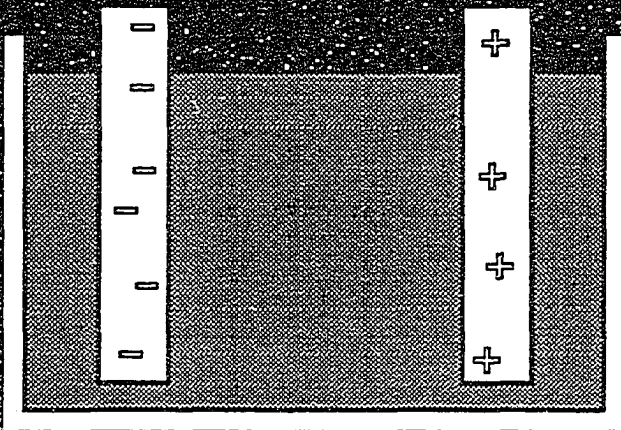
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You may recall our previous discussion of the need for a force to move electrons in a circuit. Much like a force is needed to move water through a pipe, a force is needed to move electrons within a circuit. Chemical changes taking place within the electrochemical cell of a battery cause the negative terminal to produce a surplus of electrons. Also, because of the chemical changes, the positive terminal of the cell lacks a normal supply of electrons.

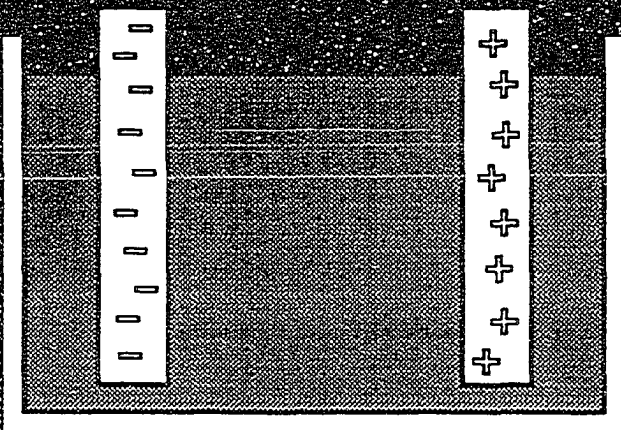
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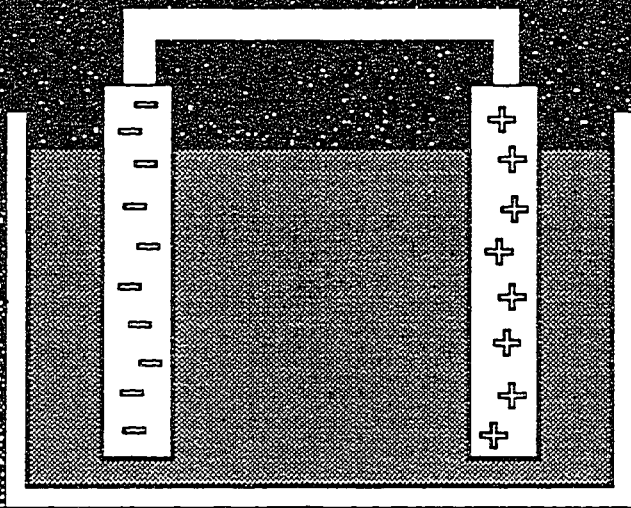
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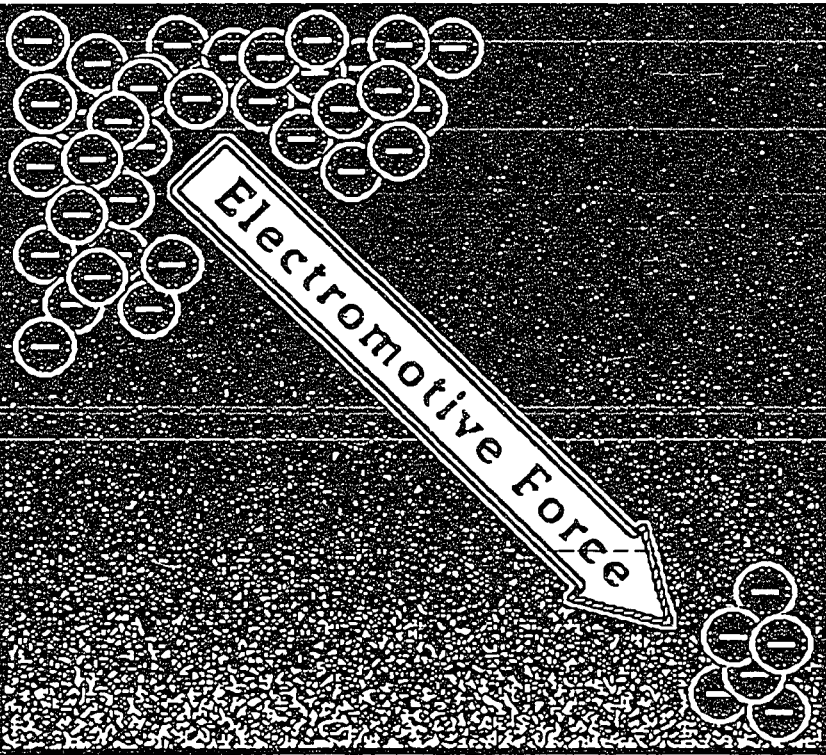
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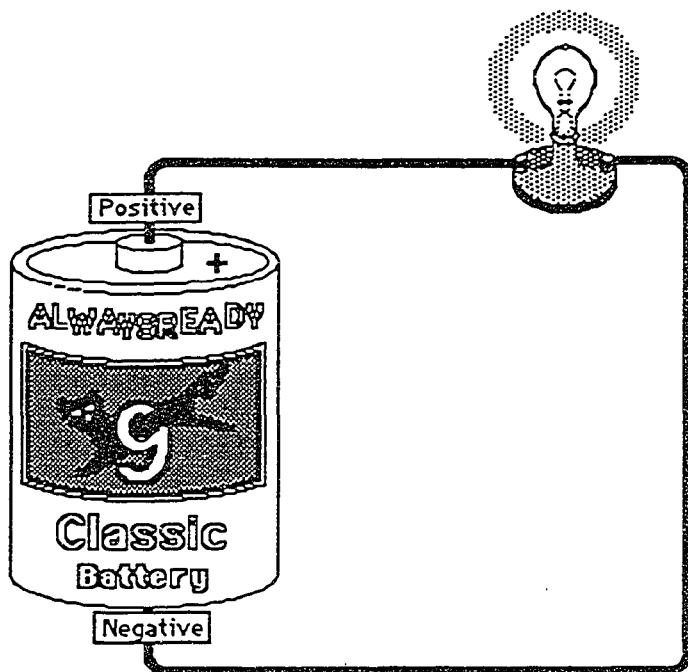
If wires that are capable of conducting electrical energy are attached to the positive and negative terminals of the battery, the surplus of electrons in the negative terminal have a path to the positive terminal which has a shortage of electrons. This movement of electrical charges is called **current**.

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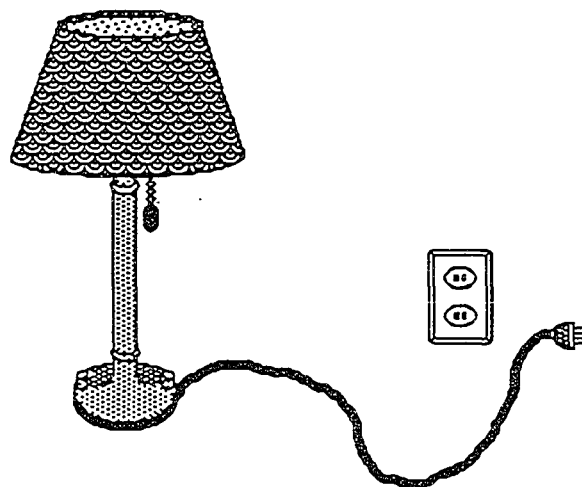
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◀ Go Back | Go On ▶



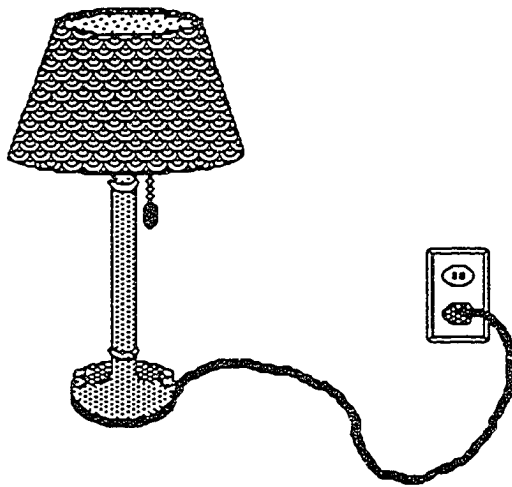
If you connect a wire to join the negative & positive terminals of the battery, the extra electrons in the negative terminal will have a path to the other terminal where electrons are lacking. If electrons will immediately start to move between the terminals, you have made an electric circuit. An electric circuit is a complete path between negative and positive battery terminals that allows electrons to move and produce an electric current.

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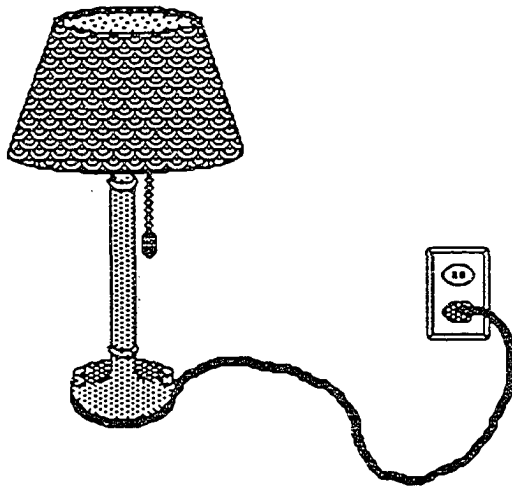
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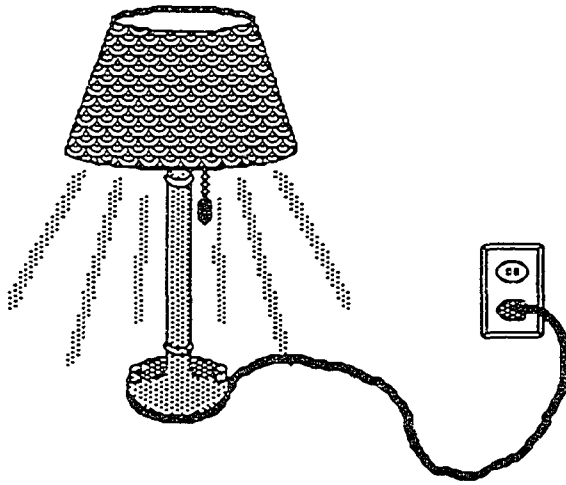
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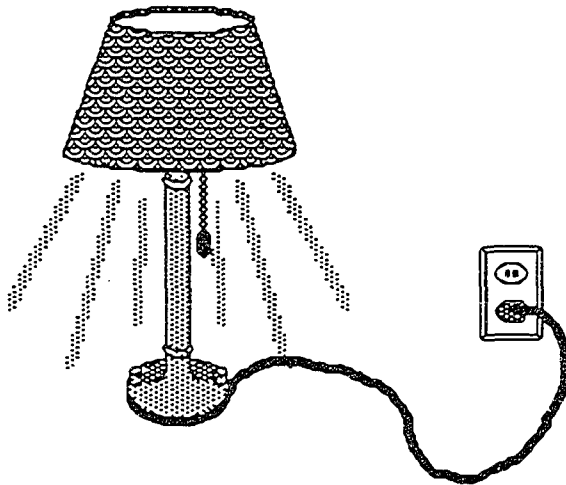
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# Measuring



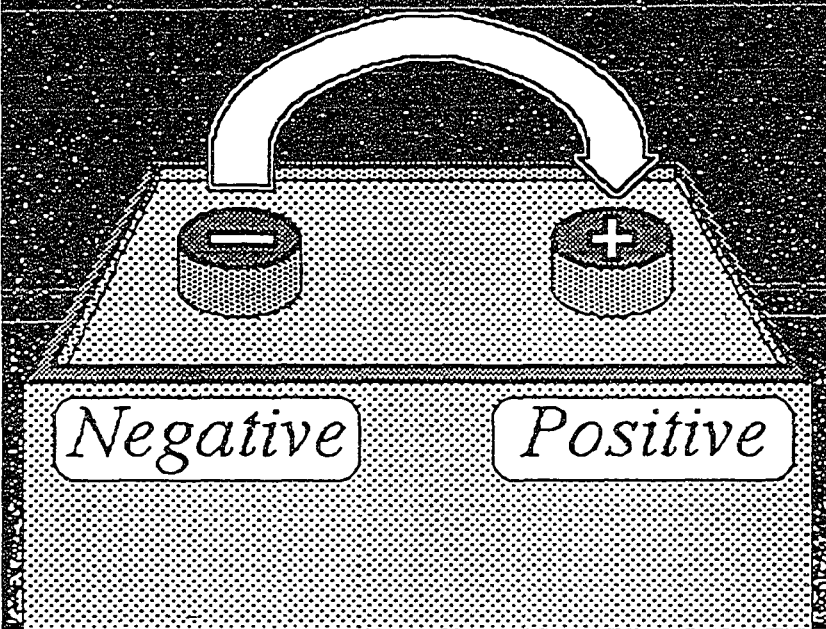
## Electrical Parameters

To this point, our discussion of electrical energy has been theoretical. That is, we have discussed in principle how electrical energy is produced and how it is transferred to devices. More specifically, we have discussed what an electric circuit is, what current is, how electrical energy (in the form of electrons) moves within a circuit, the electromotive force that moves electrons, and how that force is produced.

In this section, we want to discuss measuring electrical parameters.

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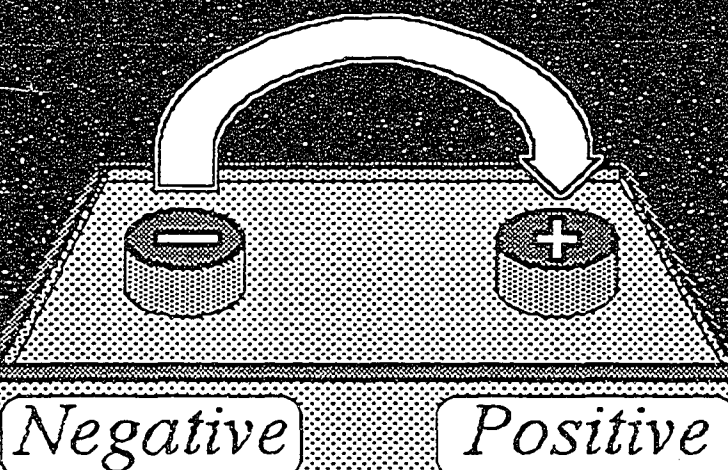
## Electromotive Force



As previously stated, a force is needed to cause electrons to move in a circuit. The force that causes electrons to move is called the electromotive force, and it is created by the difference in the number of electrons in battery terminals (or the electron potential difference).

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# VOLTAGE



A measure of the force available to move electrons is called the **voltage** (potential energy). If all other circuit parameters are kept constant, the higher the voltage, the greater the force to move the electrons. Voltage is measured in units called **volts (V)**. A voltmeter is used to measure voltage.

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N  
e  
g  
a  
t  
i  
v  
e

Number of Electrons  
Passing this Point:

0

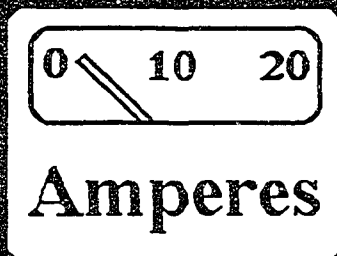


P  
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e

To use a battery's electromotive force to cause electrons to move, a path between the battery terminals must exist. A wire made of suitable conducting material can be used to form such a path. The movement of electrons is called an **electric current**. **Current (I)** is measured according to how many electrons pass a given point each second.

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N  
e  
g  
a  
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i  
v  
e



P  
o  
s  
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t  
i  
v  
e

The higher (or greater) the electric current in a wire, the more electrons are passing through the wire each second. The unit used to measure current is ampere (A); one ampere is a measure of the number of electrons that pass a given point per second.

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Direction of Eletromotive Force

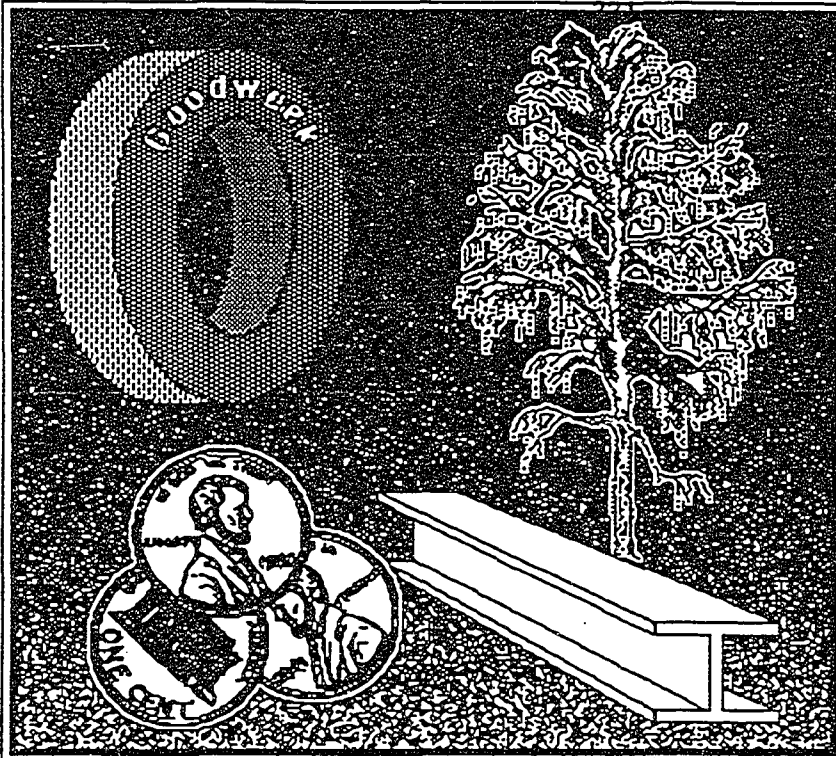
C  
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d  
u  
c  
t  
o  
r

Each device in a circuit resists or opposes the flow of electrons.

Opposition to the flow of electrons is called **resistance (R)**. The unit used to measure resistance is the ohm ( $\Omega$ ).

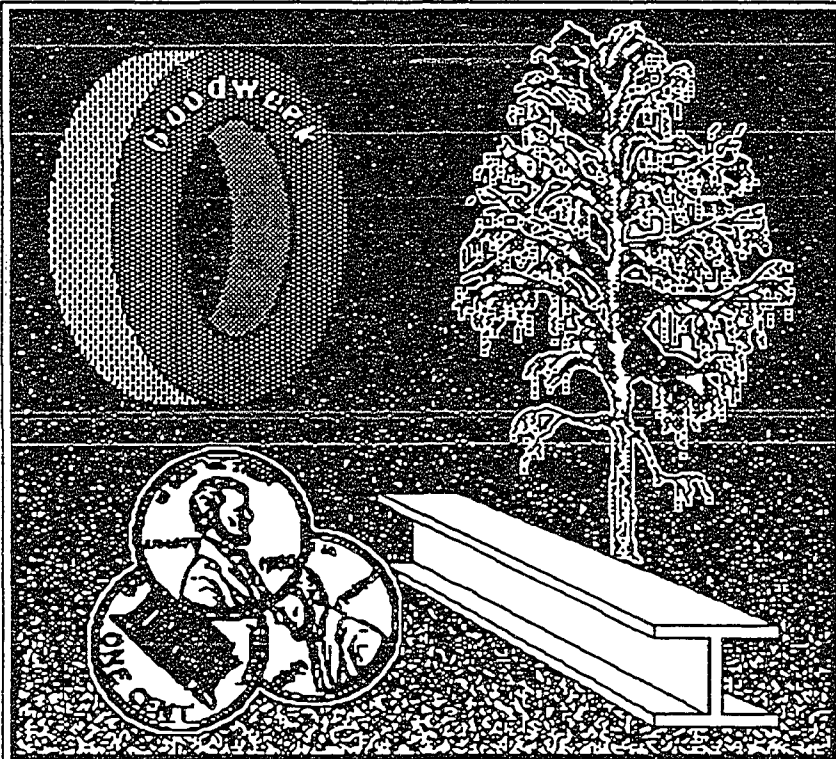
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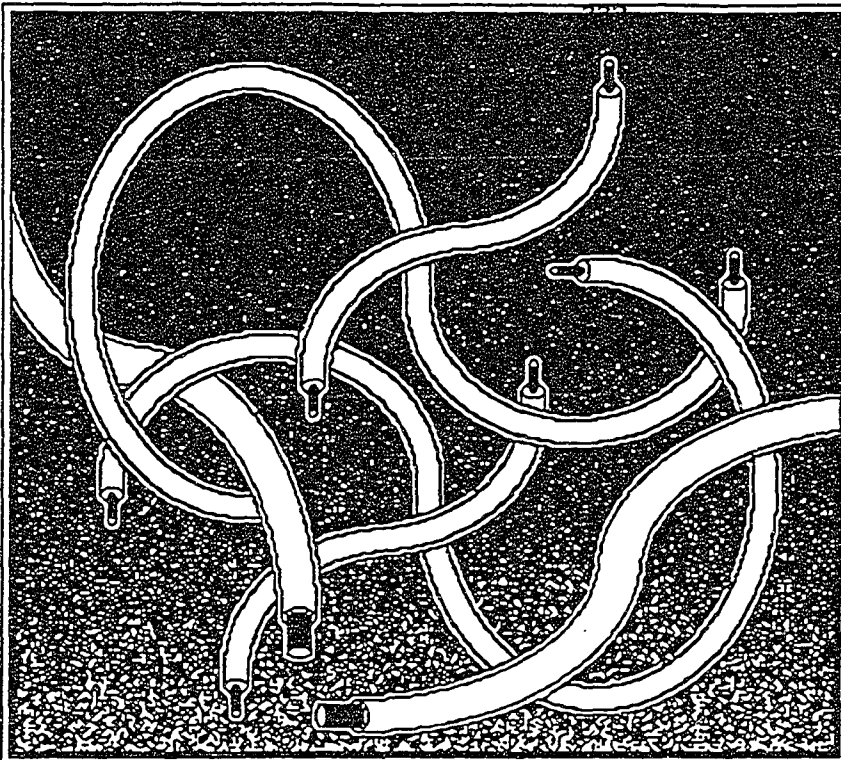
As you may recall, some materials conduct electricity better than others. For example, wires made of copper have low resistance and allow electrons to flow through them easily. Wires made of iron are poorer conductors and have more resistance, while materials like wood, glass, or rubber have enormous resistance and are called insulators. Each device in a circuit, such as a light bulb or toaster, opposes the flow of electrons & has resistance.

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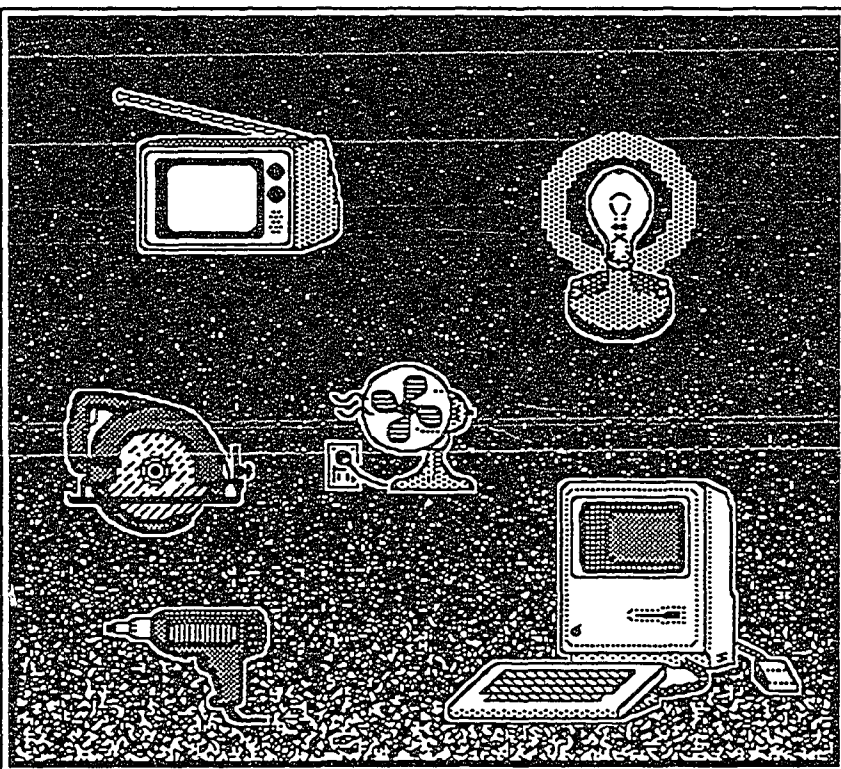
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In addition to the material used to make a wire, the resistance of a wire depends upon its thickness and length. Thin, long wires have greater resistance than thick, short wires because there is less room in a thin wire for electrons to move and a greater distance in a long wire to travel. Imagine a long narrow tunnel full of people. The people would encounter more resistance moving through the long narrow tunnel than they would moving through a short, wide tunnel.

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Each device in a circuit, such as a light bulb, computer, cassette player, fan, or toaster, opposes the flow of electrons. This opposition or resistance is measured in ohms.

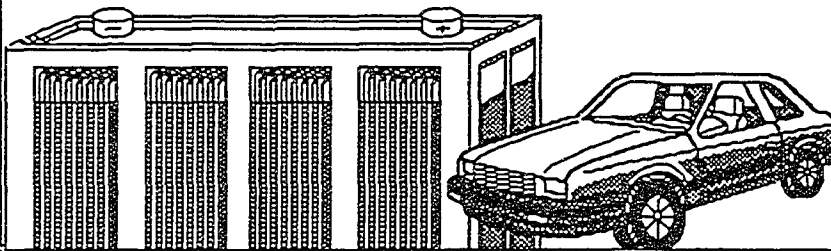
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# Ohm's Law

$$=$$

\*When experimenting with simple electrical circuits in the early 1800s, Georg Ohm, a German school teacher, discovered the relationship that exists between the voltage, current, and resistance in an electrical circuit. His discovery, known as Ohm's Law, states that the current in a wire is equal to the voltage divided by the resistance.

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For example, suppose that an automobile with a 12-V battery has headlights whose resistance are 4 ohms. When the lights are on, the current required may be calculated as shown here.

The resistance for just the parking lights is 3 ohms. When the parking lights are on, how much current is required?

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Radio

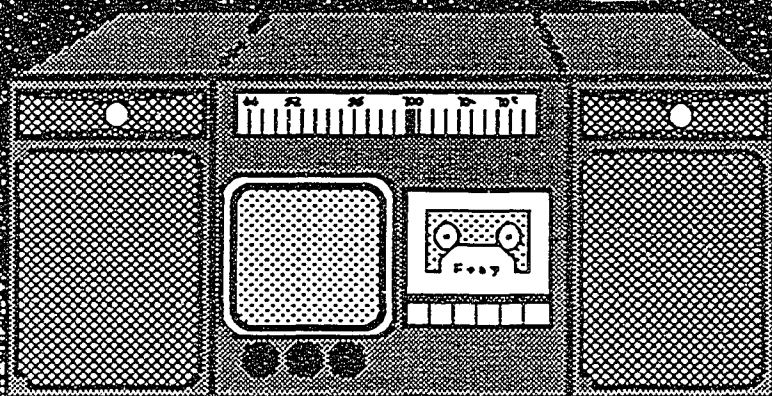
$$R = 2$$

Cassette Player

$$R = 3$$

Television

$$R = 4$$



The current required for the television is 15 amperes. What is the voltage needed to operate the television?

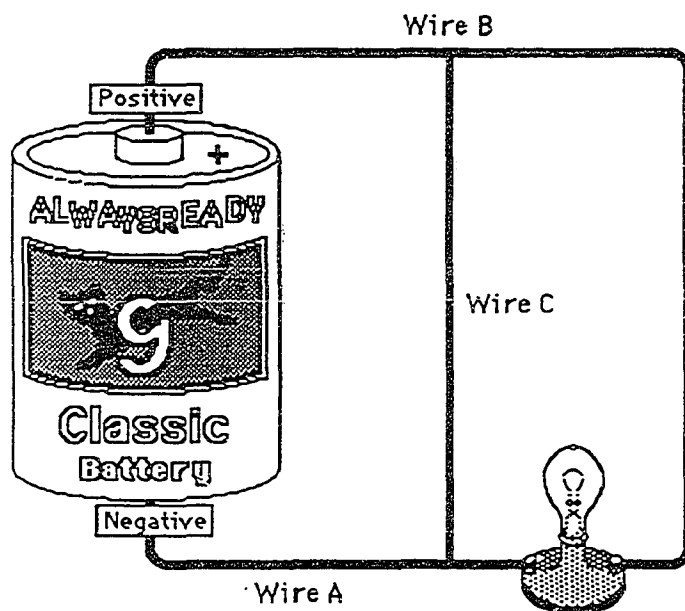
How many 6 volt batteries are required to operate the boom box?

How many 12 volt batteries?

Suppose that only 9 volts were needed to power Joanna's boom box, what would be the current required for the cassette player?

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## Short Circuit

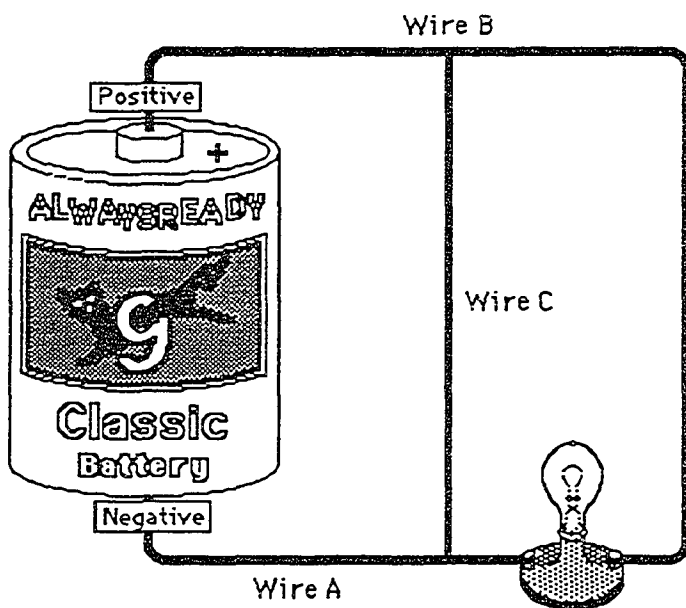


Have you ever used an electric appliance only to be startled by a shower of sparks, & a room plunged into darkness? What caused this to happen?

In this illustration there are 3 wires in the circuit. Wire A connects the negative battery terminal & the bulb. Wire B connects the bulb & the positive battery terminal & wire C connects wires A & B. This configuration is known as a short circuit.

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# Short Circuit

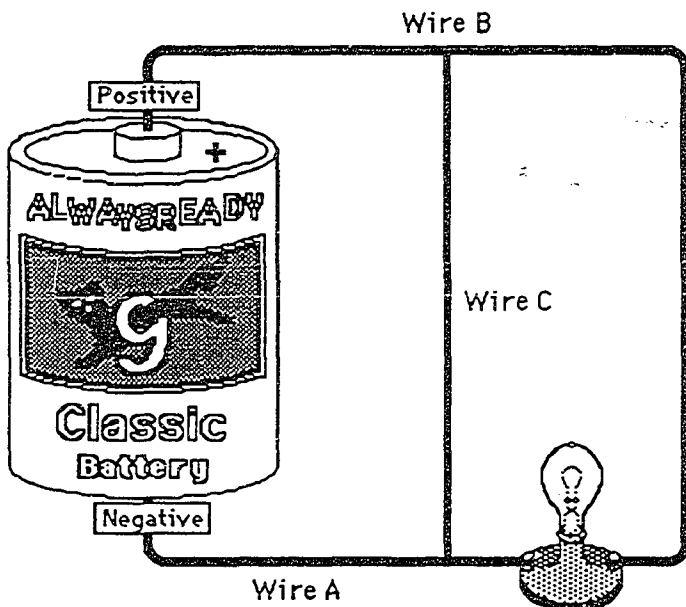


A short circuit is a pathway with very low resistance that completes an electric circuit. The bulb in this circuit will not work because wire C causes a short circuit.

Why?

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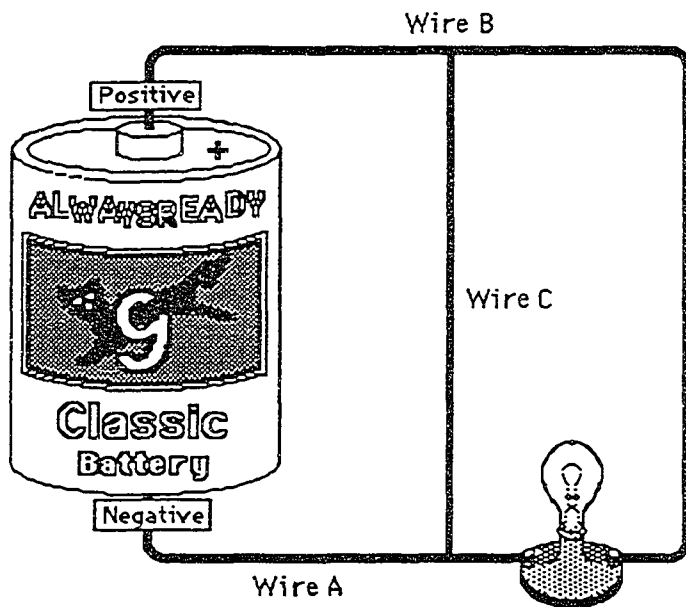
# Short Circuit



Like water flowing down hill, electrical charges will seek the path of least resistance. As mentioned earlier, the light bulb, like other devices, has a great deal of resistance. When wire C is in place, a path exists for the electrical charges to avoid the resistance of the light bulb while still completing the circuit. A short circuit is a pathway with very low resistance that completes an electric circuit.

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# Short Circuit

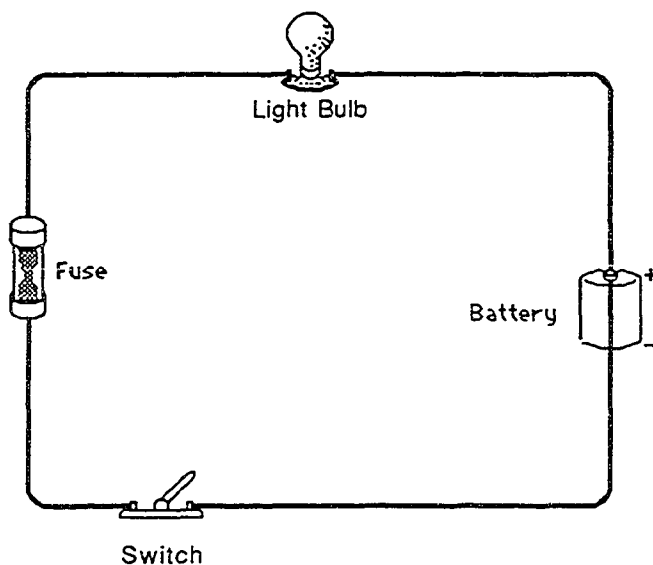


If wire C were removed, the light bulb would work and a short circuit would not occur.

Short circuits are dangerous. The low resistance of a short circuit allows so much current to flow through the wire that the wire can heat up and cause a fire. Even if the wire does not get hot enough to cause a fire, it can discharge a battery very quickly.

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# Electric Circuit



As we defined earlier, an electric circuit is a complete path between negative & positive battery terminals that allows electrons to move and produce an electric current. In a circuit there must be a source of electrons to be transferred within the circuit. Conductors, usually wires, are needed to connect all the parts of a circuit. These parts may include switches, fuses, and electrical devices.

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Conductor



Switch



Fuse



Ammeter



Voltmeter



Resistor



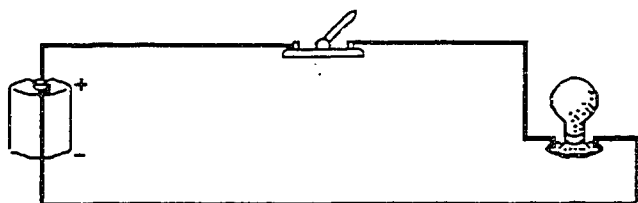
Battery of Cells  
in Series

To illustrate parts of an electrical circuit, the symbols shown here will be used.

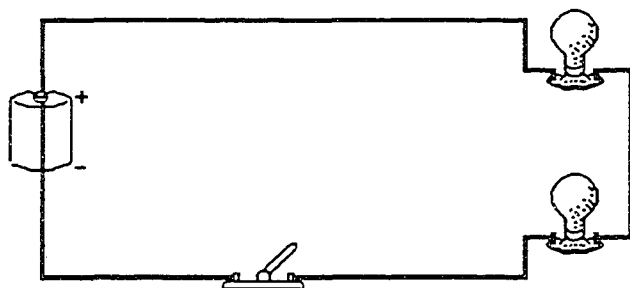
NOTE: These symbols and their definition are always available by clicking on the SYMBOLS button in the lower-right corner.

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Circuit #1



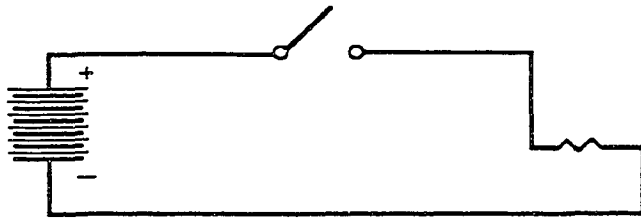
Circuit #2

Sketch circuits 1 and 2 using the symbols available.

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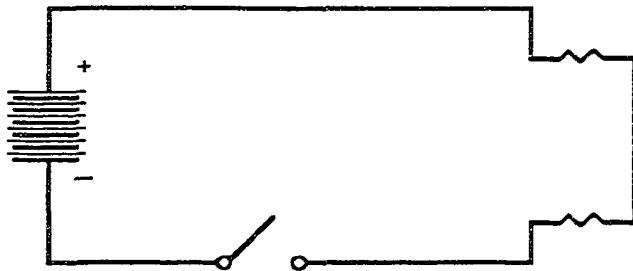
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Circuit #1

.....

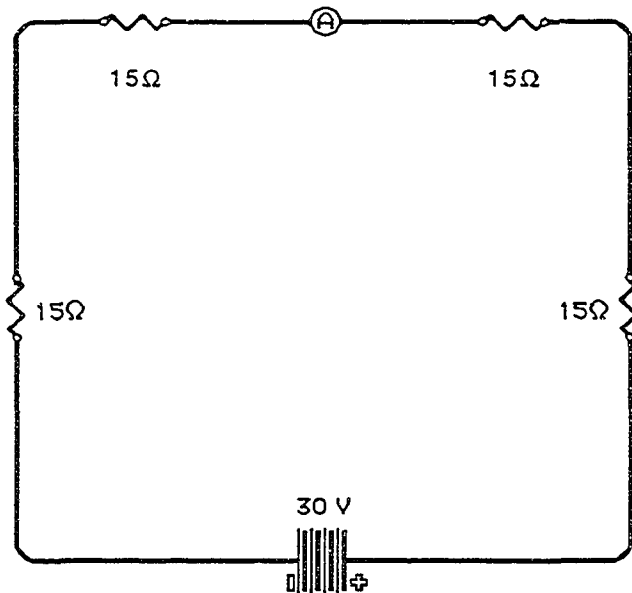


Circuit #2

Your sketches of circuits 1 and 2 using the symbols should resemble these.

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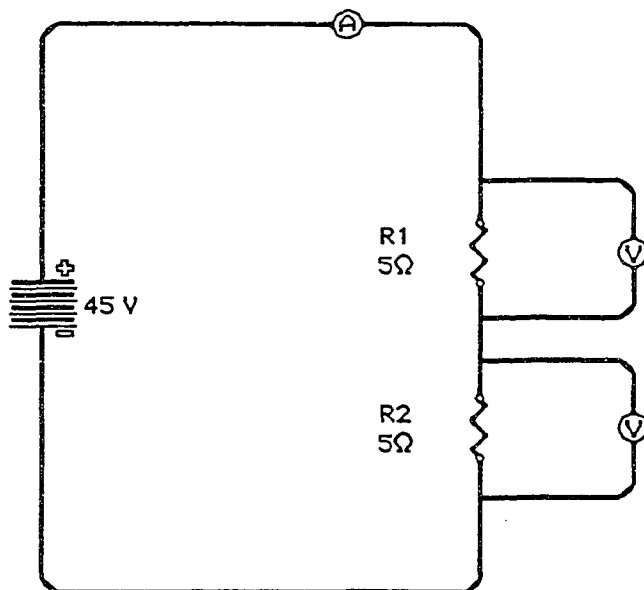


Four 15 ohm resistors are connected in series to a 30 volt battery.

What is the current in the circuit?

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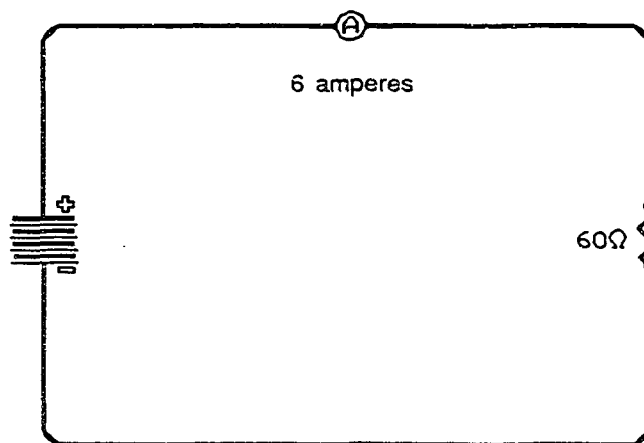


A  $5.0\text{ ohm}$  resistor and  $10.0\text{ ohm}$  resistor are connected in series and placed across a  $45.0\text{ V}$  potential difference.

- What is the effective resistance of the circuit?
- What is the current through the circuit?
- What is the voltage across each resistor?
- What is the total voltage across the circuit?

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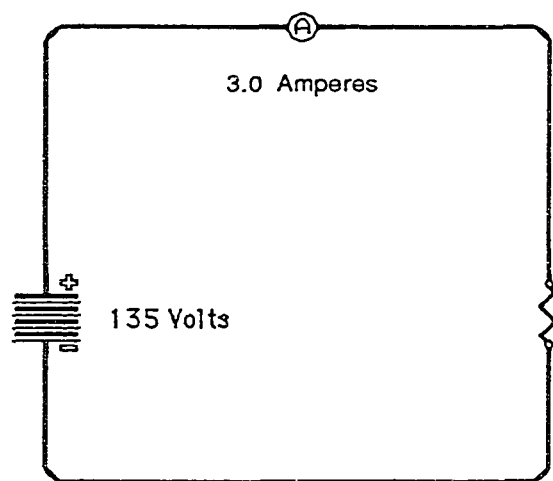


A circuit with a current of  $6$  amperes has  $60\text{ ohms}$  of resistance.

What is the voltage of the battery?

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A current of 3.0 amperes passes through a hair dryer when connected to a 135 volt electric outlet.

What is the dryer's resistance in ohms?

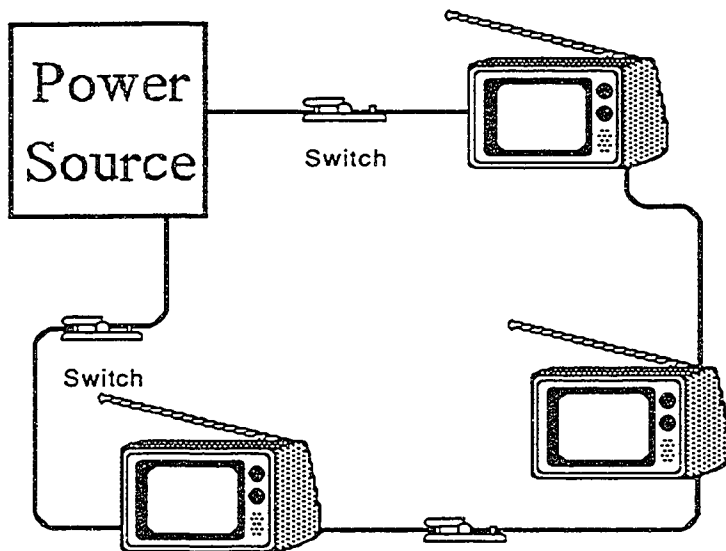
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*Go to the Symbol Key*

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# Series Circuits

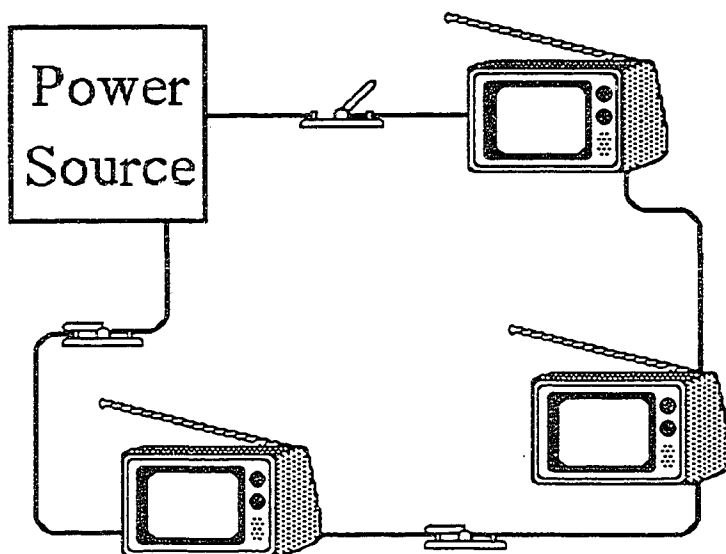


To this point, we have worked primarily with circuits that have included a single device or appliance. There are, however, circuits in which more than one device is connected to a power source. One method in which several devices can be connected in a circuit is called **series** wiring. In a series circuit, the multiple devices are connected one after the other. In a **series circuit**, the same current must flow through each device in the circuit.

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# Series Circuits

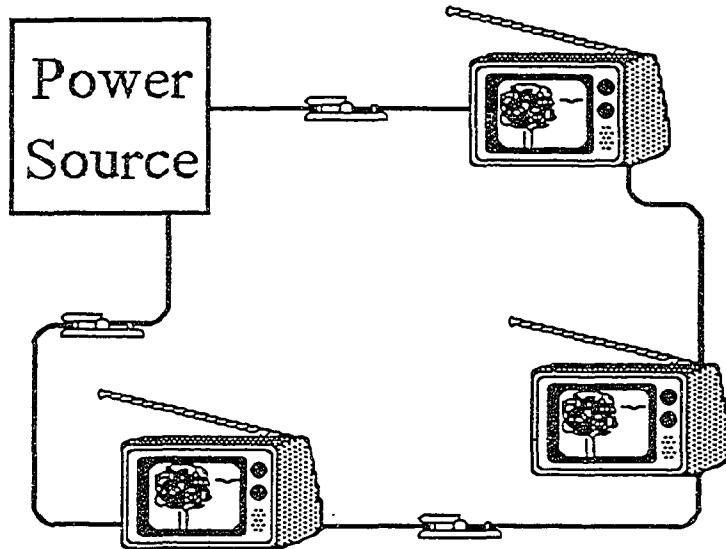


The same current must flow through each device in a series circuit. As you can see in the illustrations, because it is a single circuit, all of the televisions are ON or all of the televisions are OFF. If the current is stopped by one of the switches, the path for the current is broken and none of the devices in the circuit can work. What are some advantages of series circuits? What are some disadvantages of series circuits?

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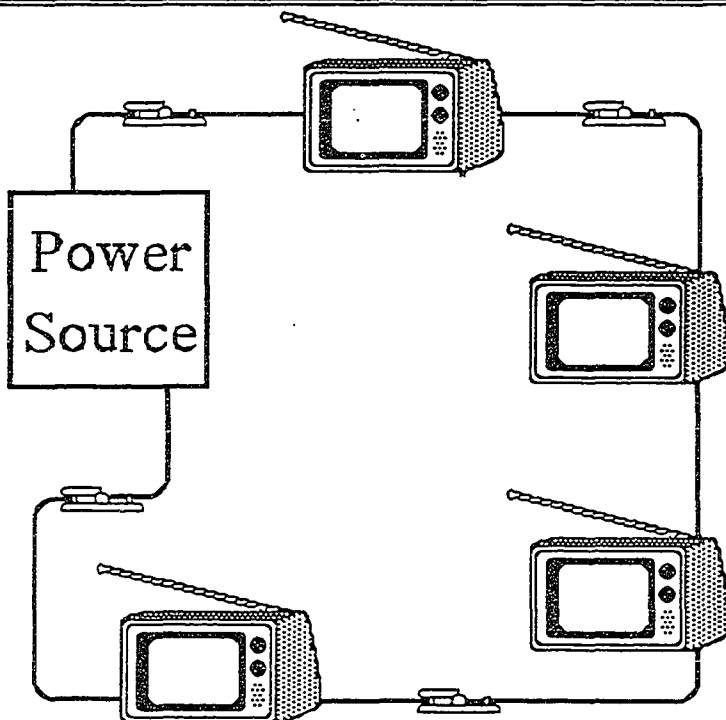
# Series Circuits



When most you have learned about the way circuits operate and how current flows through a circuit, it is possible to construct a series circuit with 4 devices that 3 devices work with one. Many students think that it is possible to construct a series circuit with 4 devices, which 3 of the devices work with one. Do you think that these circuits are correct? Sketch the circuit that justifies your answer. Describe how the current flows.

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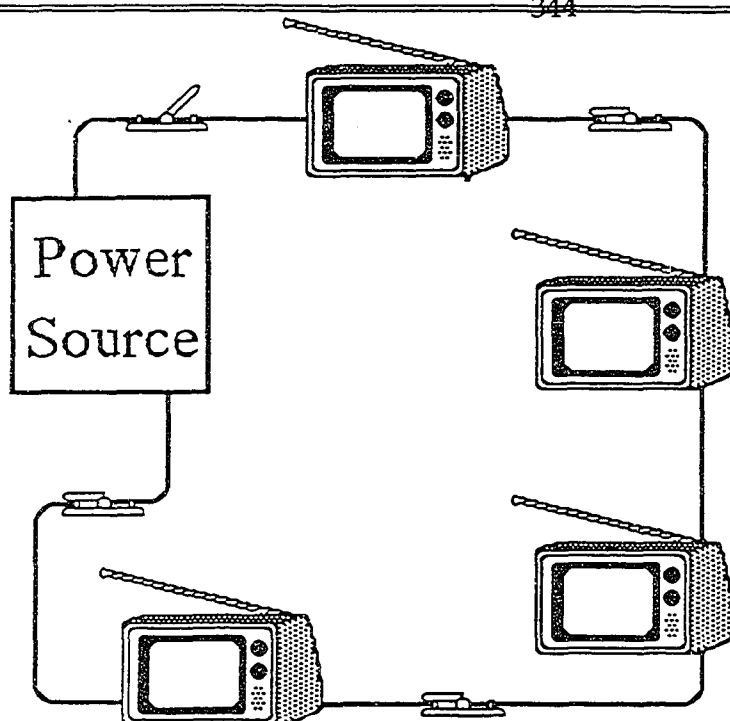
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Students who believe that it is possible to construct a series circuit with 3 devices that operate and 4 that does not are incorrect. In a series circuit, no part of the circuit can be switched off without turning off the entire circuit. In other words, all devices in a series circuit must be operational for any of the devices to work. How can we illustrate this?

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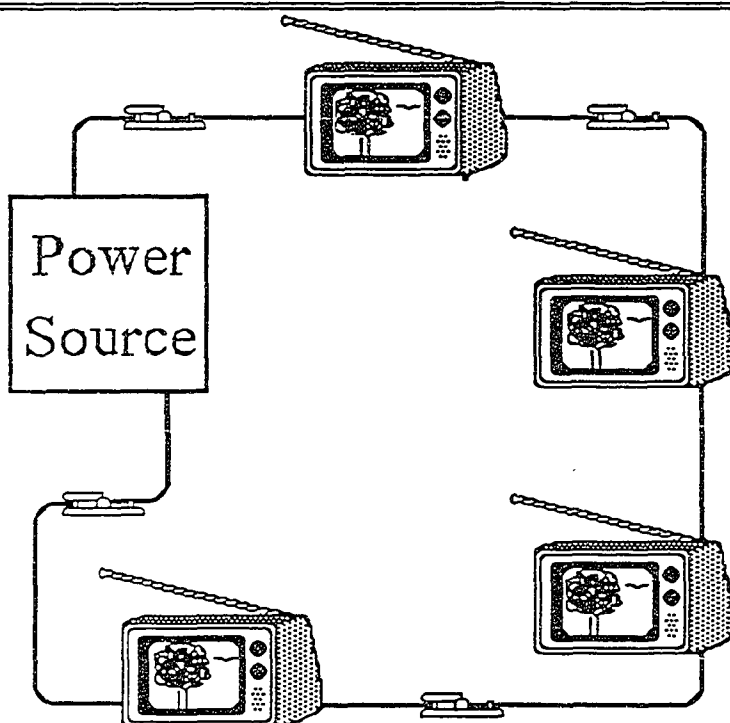
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The series circuit on this screen has 4 televisions. The ON/OFF switch for each television is next to that television. The switches may be changed by clicking on them with the mouse. With each television switch in the ON position, describe what happens to the televisions.

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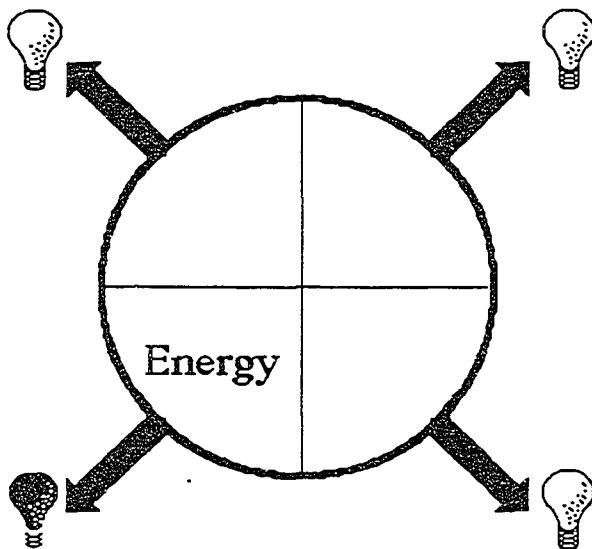


Move one of the television switches to the OFF position. Note what happens to that switch in the circuit. Examine the circuit. Describe what happens to the televisions, what occurred physically in the circuit and how current flows through the circuit.

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# Distribution

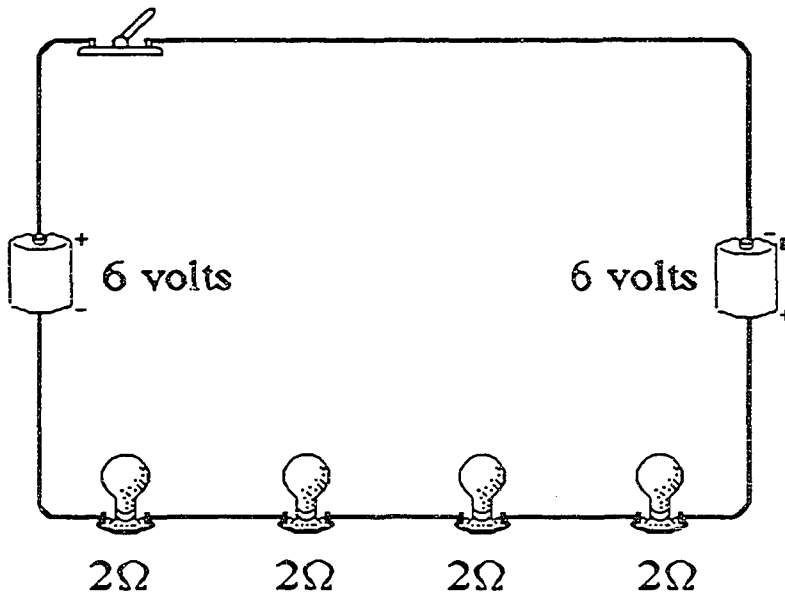


As you may recall in a series circuit either all of the devices are on or they are all off. If the current is interrupted anywhere in the circuit, none of the devices will work. Now, we will examine in greater detail the Distribution of electrical energy within a series circuit: that is, how the energy is divided among the devices in a series circuit.

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# Distribution



In this illustration you are given the resistance of each bulb and the voltage of the batteries. Calculate the amount of current that would flow if only one bulb were in the circuit.

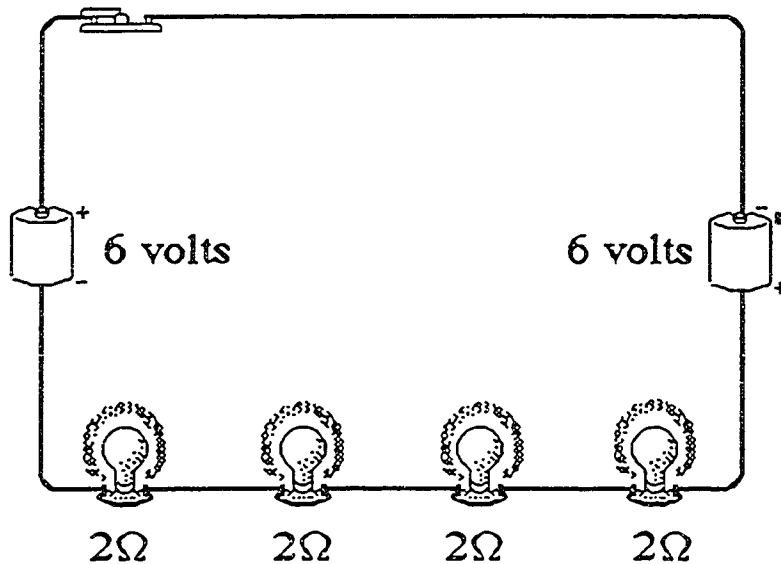
(Remember:  $I = V/R$ )

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# Distribution

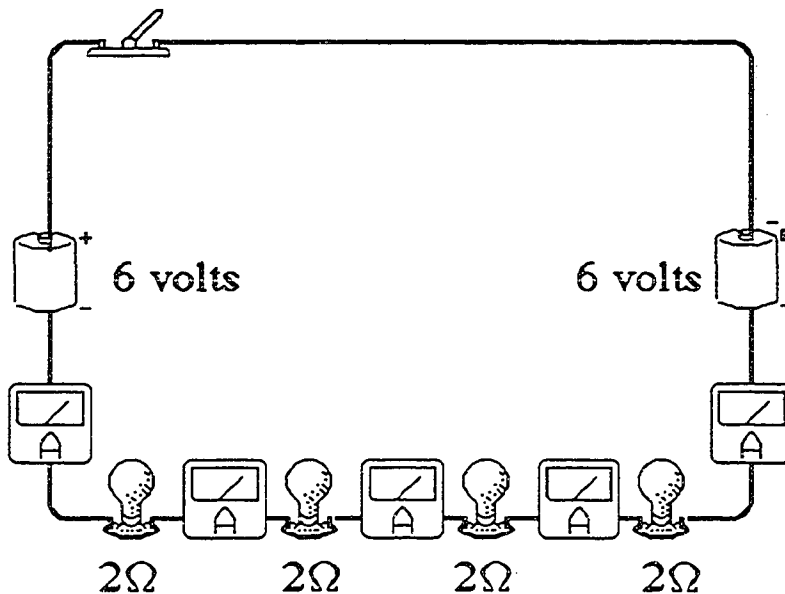


When you add multiple devices to a simple circuit creating a series circuit, you increase the resistance ( $R_1 + R_2 + R_3 + R_4$ ) and the current flow is less, but all the devices get the same amount of current. Therefore, the brightness of all four bulbs is the same.

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# Distribution



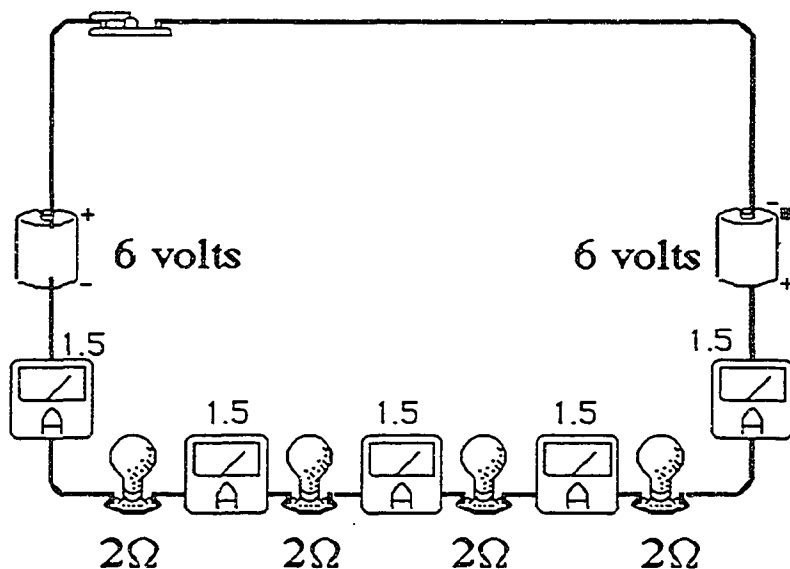
Remember that we can measure the current in a circuit with an ammeter. In this illustration, five ammeters have been connected to measure the current before and after each device in the circuit. The purpose of this is to measure which device receives the most current within the circuit.

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# Distribution

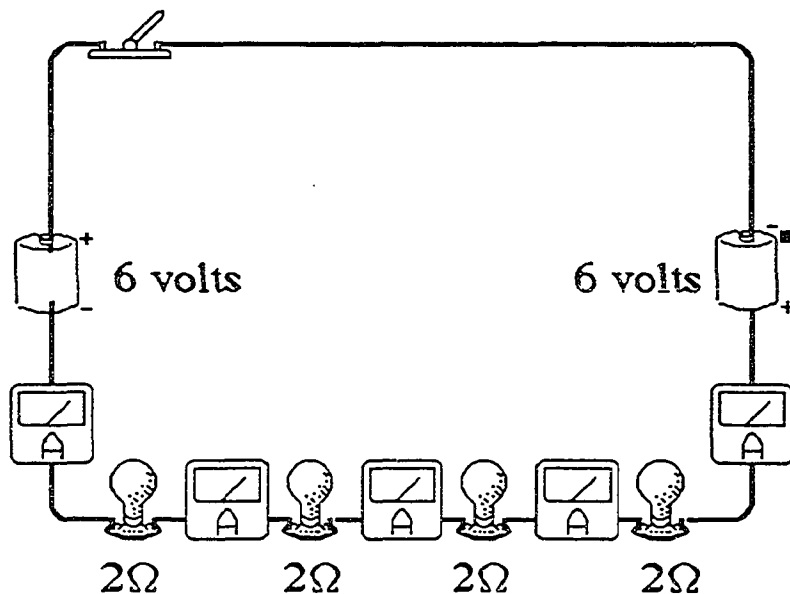


Notice that the ammeter readings are the same at all locations within the circuit. Thus, in a series circuit, each device receives the same amount of current. The current flowing back to the battery is the same as the amount flowing out.

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# Distribution



You have already calculated the current that would flow if only one bulb were in the circuit. To calculate the current needed for the entire circuit, use the following formulas:

$$R = (R_1 + R_2 + R_3 + R_4)$$

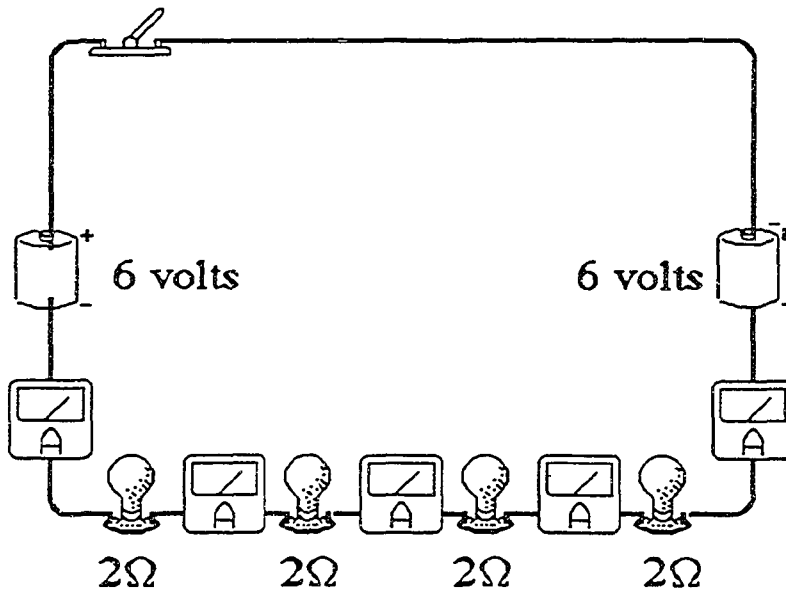
$$I = V / R$$

Calculate the current needed for the entire circuit.

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# Distribution



By comparing your calculations you probably noticed that the current for all four bulbs is equal to one-fourth of the current calculated for each individual bulb. In addition, you probably noticed that the resistance is four times as great for all four bulbs as it is for each individual bulb.

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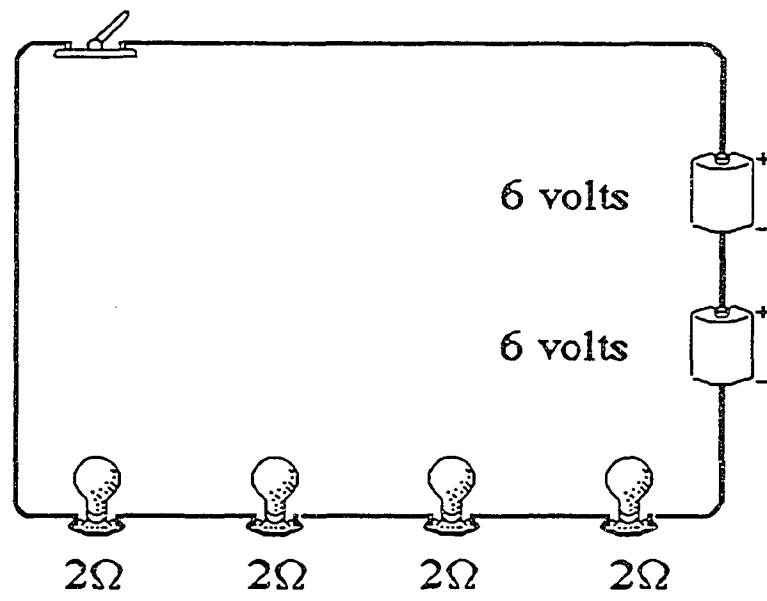
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## SIMULATION BRANCH

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# Distribution

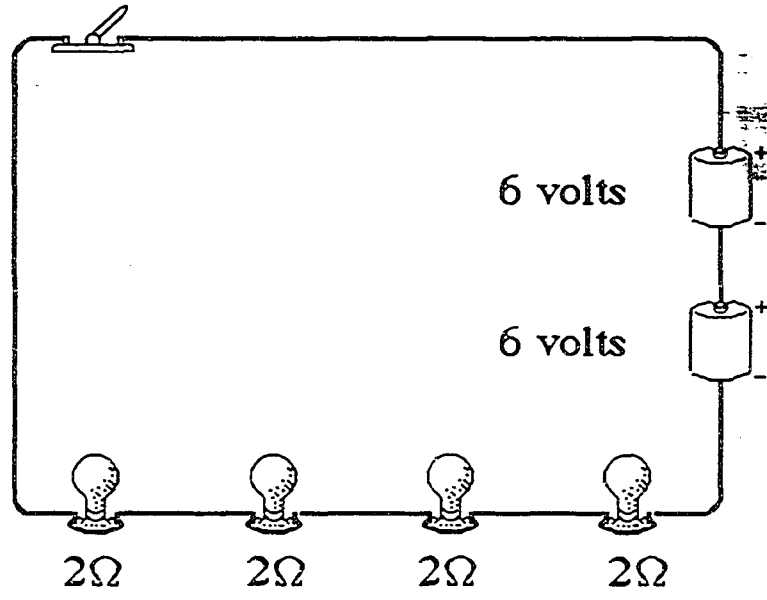


You have tested how electricity flows through a series circuit. As you may recall, in a series circuit, either all of the devices are ON or they are all OFF. If the current is interrupted anywhere in the circuit, none of the devices will work. Now, we will examine in greater detail the distribution of electrical energy within a series circuit; that is, how the energy is divided among the devices in a series circuit.

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# Distribution

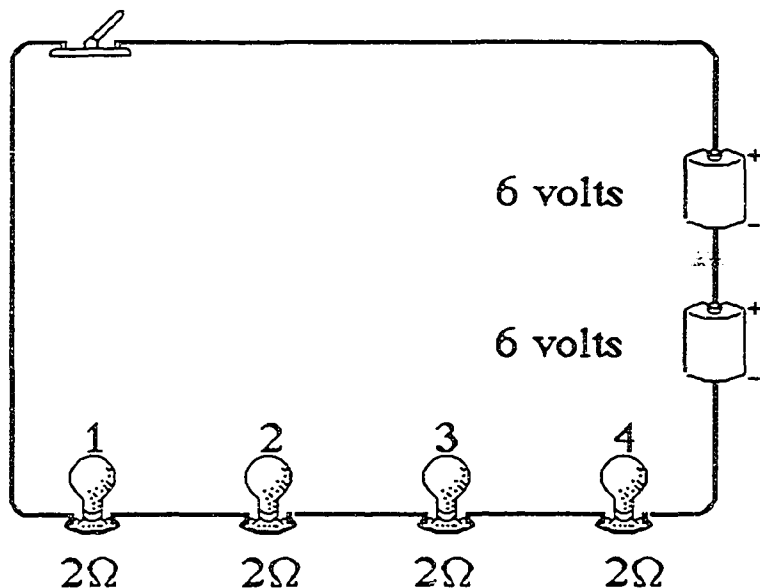


In this series circuit, there are four light bulbs. Given your knowledge of how series circuits operate and your current notes on Ohm's Law, do you think there will be a difference in the brightness of the bulbs when the circuit is switched on? Which one will be the brightest? Which one will shine the least? Will they have the same brightness? Describe how the current flow will affect the brightness of the bulbs.

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# Distribution



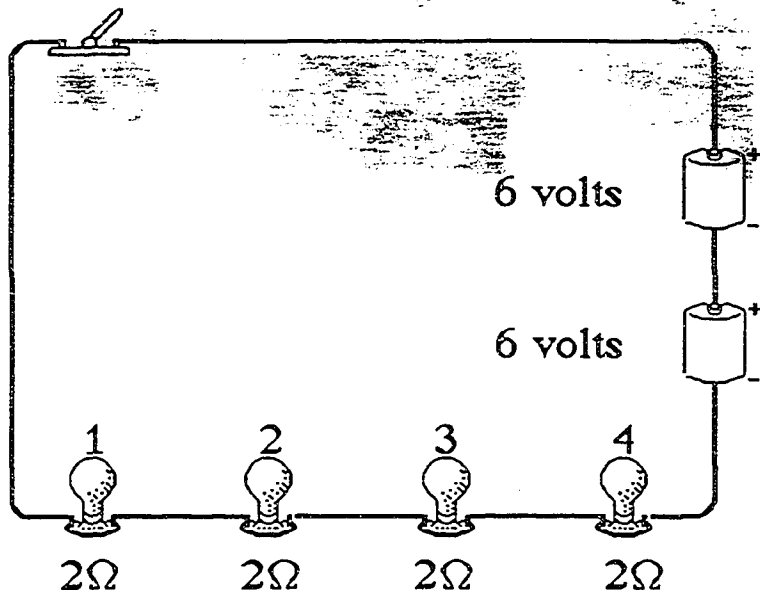
Before studying electricity, some students think that bulbs 3 and 4 will receive less electrical energy than bulbs 1 and 2. Others think that bulbs 1 and 2 receive less electrical energy than bulbs 3 and 4.

Do you think these students are correct? Explain why or why not.

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# Distribution



Given the resistance of each bulb and the voltage of the batteries, calculate the amount of current that would flow if only ONE bulb were in the circuit.

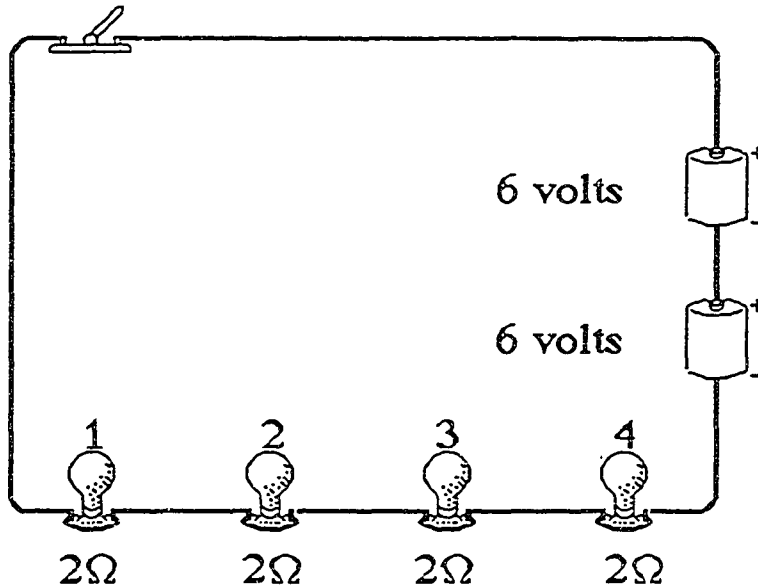
(Remember,

$$I = \frac{V}{R}$$

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# Distribution



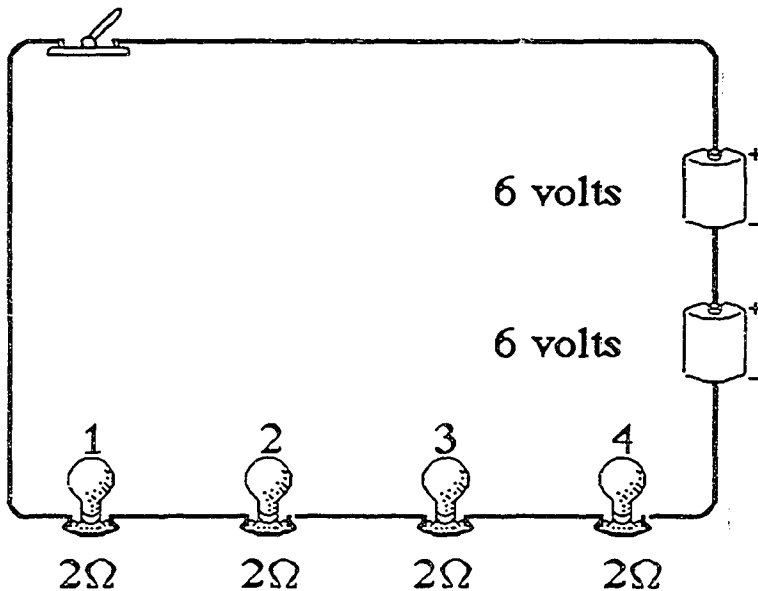
Student who think that there is a difference in the brightness of the bulbs are incorrect. How can we illustrate this fact?

Using the simulation, test this series circuit that has four bulbs each with a resistance of 2 ohms. Is there a difference in the brightness of the four bulbs? (Click the switch to turn the circuit on.)

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# Distribution



No. This is because the current is divided equally among all of the light bulbs.

When you add multiple devices to a simple circuit, creating a series circuit, or increase the resistance.

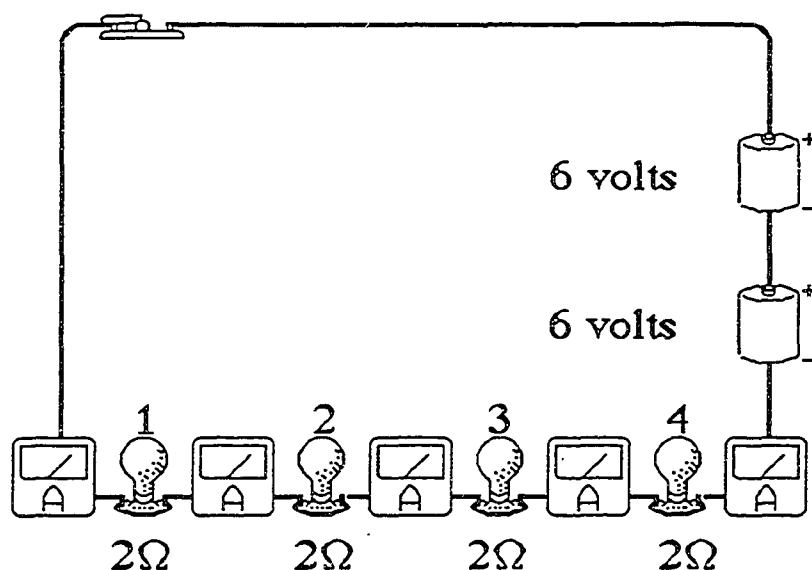
$(R_1 + R_2 + R_3 + R_4)$  and the current flow is less, but all the devices get the same amount of current.

That is, the current is divided equally among all of the light bulbs. How can we illustrate this fact?

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# Distribution

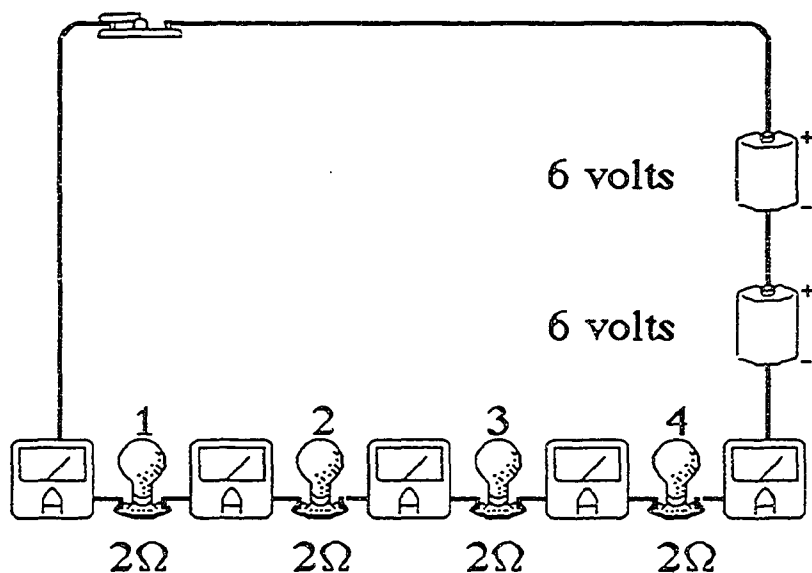


Remember that we can measure the current in a circuit with an ammeter. In this series circuit, five ammeters have been connected to measure the current before and after each bulb in the circuit. The purpose of this is to measure whether the current changes in the circuit. Click on the ammeters & record the readings for the current throughout the circuit. What did you discover?

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# Distribution

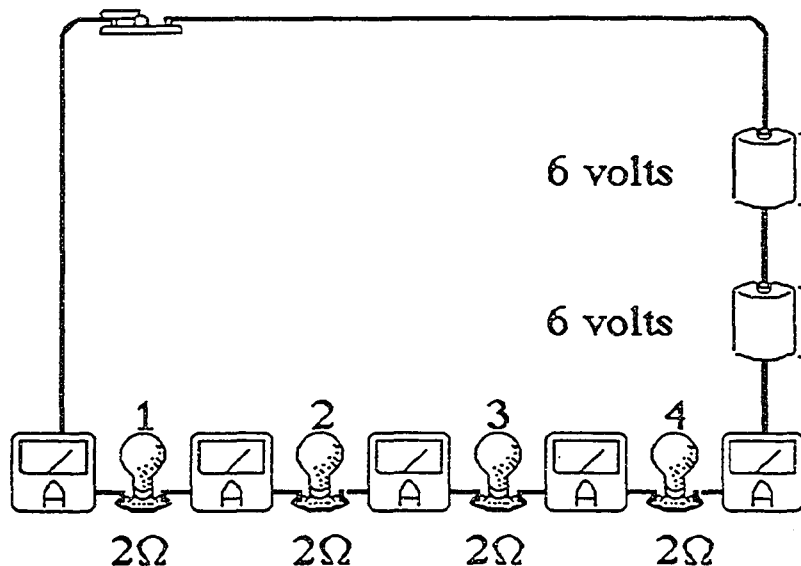


The ammeter readings are the same at all locations within the circuit. Thus, in a series circuit, each device receives the same amount of current and the amount of current flowing back to the battery is the same as the amount flowing out.

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# Distribution



You have already calculated the current that would flow if only one bulb were in the circuit. To calculate the current needed for the entire circuit, use the following formula:

$$R = R_1 + R_2 + R_3 + R_4$$

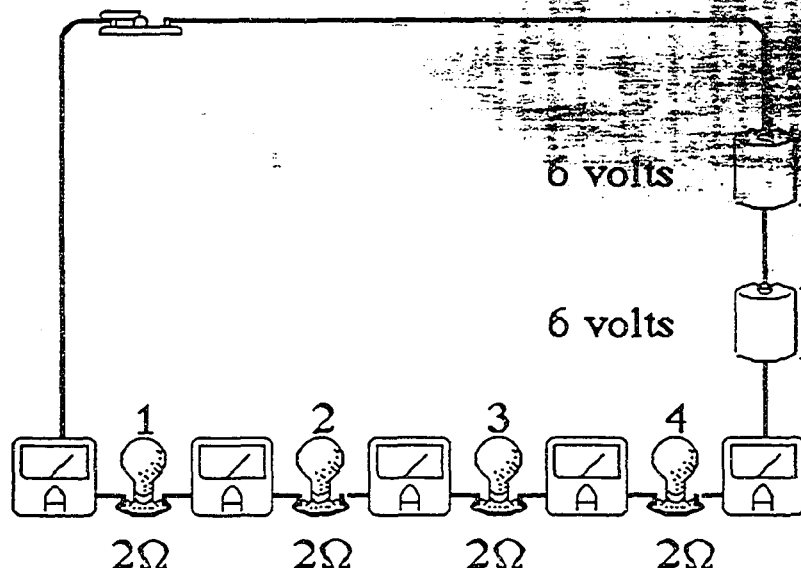
$$I = V / R$$

Calculate the current needed for the entire circuit.

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# Distribution



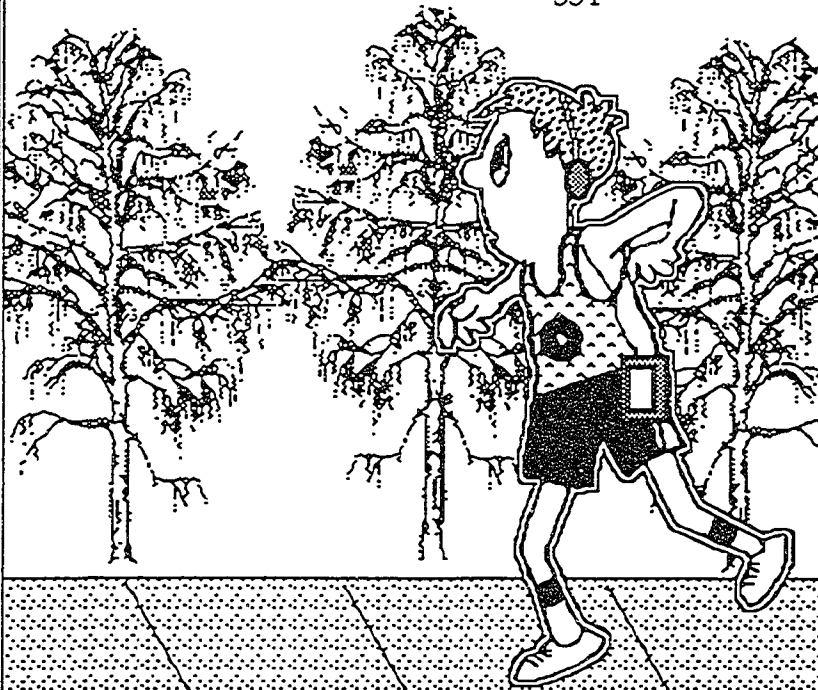
What is the difference between the current calculated for each individual bulb and all four bulbs together?

The current for all four bulbs is equal to one-fourth of the current calculated for each individual bulb. In addition, you probably noticed that the resistance is four times as great for all four bulbs as it is for each individual bulb.

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Trenton runs five miles every afternoon following his English course. He likes to run on the trails in the woods near his home. Typically, he runs alone with his walkman and listens to the radio or a Roxette cassette tape. Today, while Trenton was running, his walkman would not work because the batteries were dead. What does this mean?

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R. I. P.

Always Ready  
Battery

You too have probably stated that the batteries are dead when, for example, your flashlight does not work. What is meant by the phrase, "the batteries are dead"?

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A diagram illustrating the concept of electromotive force. It features a large, dark, textured rectangular area. In the top-left corner, there is a cluster of approximately 15 small circles, each containing a minus sign (-). In the bottom-right corner, there is a smaller cluster of approximately 5 such circles. A large, white, diagonal arrow points from the top-left cluster towards the bottom-right cluster. The arrow is labeled "Electromotive Force" in a bold, sans-serif font.

As you may recall from our experience with simple and series circuits, it is the electromotive force (or potential energy) of the battery that causes the electrons to move. The electromotive force generates the electrical current that passes through each device. The greater the resistance in each device, a greater electromotive is required to provide current.

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A diagram of a battery. It consists of two vertical rectangular plates. The left plate is labeled with minus signs (-) and the right plate is labeled with plus signs (+). The plates are partially submerged in a dark, textured liquid. A white wire connects the top of the left plate to the top of the right plate, forming a loop. The entire battery assembly is set against a dark, textured background.

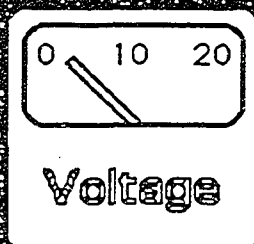
The electromotive force loses some of its strength each time it must provide current. Some of the chemical energy stored in the battery is consumed each time it is used to produce current, and thus when a battery is "dead," it is because it can no longer produce the excess of electrons in the negative terminal to supply the positive terminal that is lacking electrons.

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# A M E S

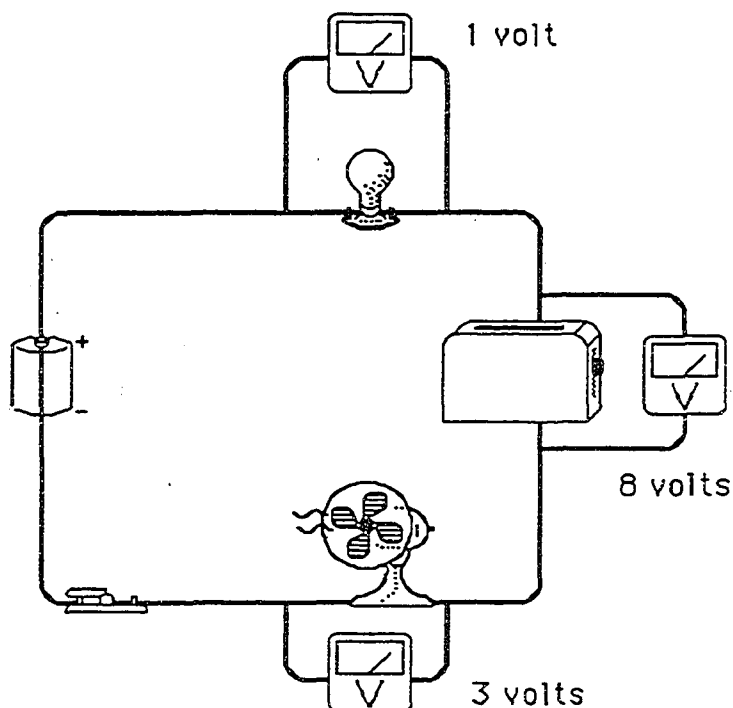
The electromotive force in a battery can be compared to the force that is created in a water tower.



As you may recall, the electromotive force is measured with a device called a voltmeter. In a circuit, the electromotive force of the battery supplies the "push" to maintain the current. This is a bit like a water tower, which supplies the water pressure to maintain the flow of water in pipes. As the electrical current passes through a device having some resistance, some of the "electrical pressure" or voltage is reduced.

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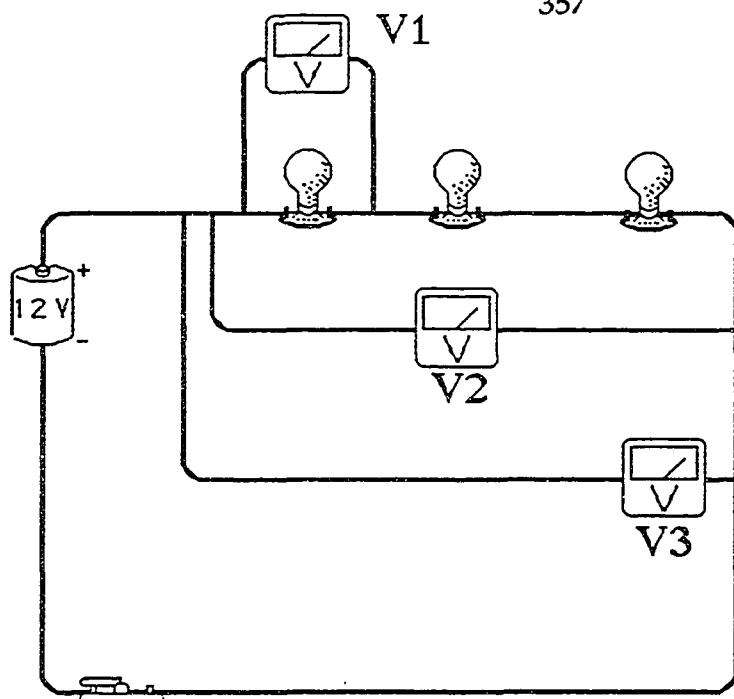
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This can be measured by placing a voltmeter across the device when current is flowing through it. In this circuit, voltmeters have been attached across various devices having different resistances. As you can see from the voltmeter readings, the voltage drop for the toaster required the greatest amount of electromotive force; thus, more electromotive force was required to overcome the resistance of the toaster than was required for the other devices.

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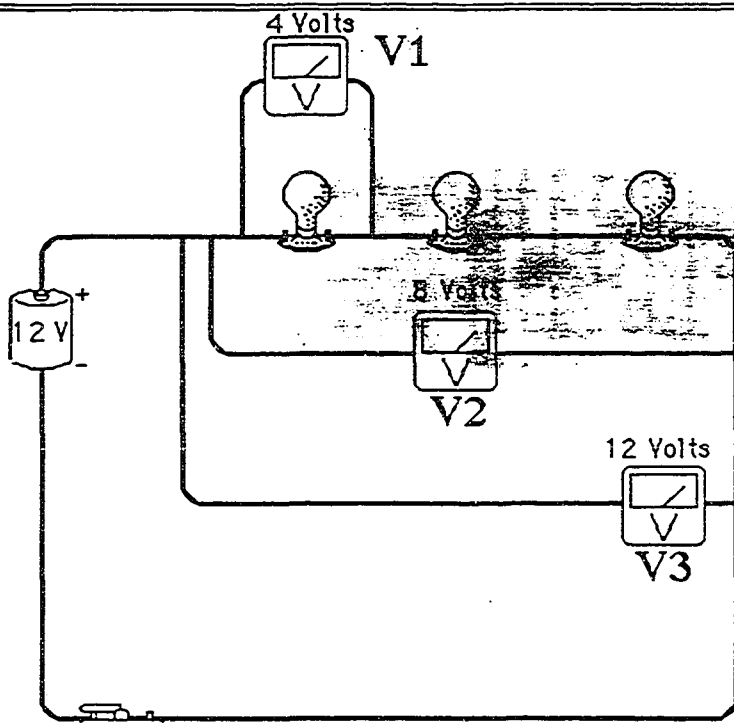
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Three voltmeters have been connected to this circuit. Notice that voltmeter 1 (V1) is measuring the voltage across the first device. Voltmeter 2 (V2) is measuring the voltage across devices 1 and 2. Voltmeter 3 (V3) is measuring the voltage across all three devices.

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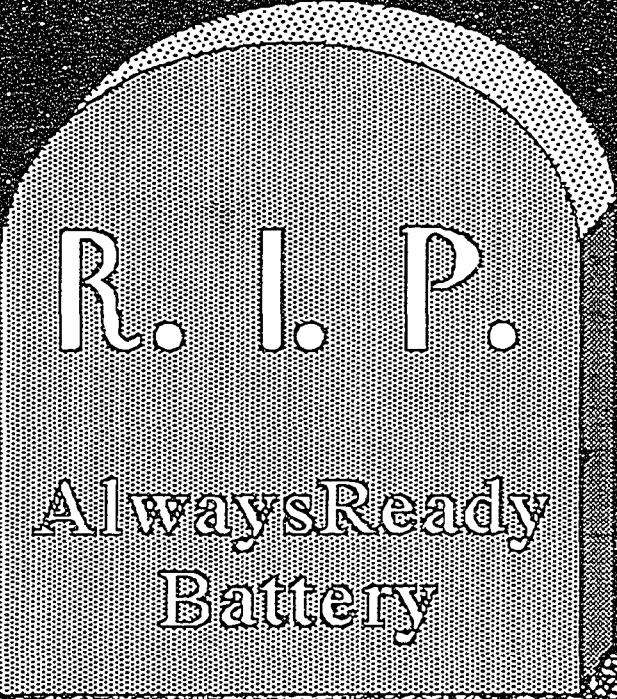
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As you can see, when voltage is measured across multiple devices the voltage increased. If we add all the voltage drops in a series circuit, they add up to the total electromotive force of the battery. When a battery is "dead" it is the electromotive force has been used up. That is, the battery can no longer produce the excess of electrons in the negative terminal to supply the + positive terminal that is lacking electrons.

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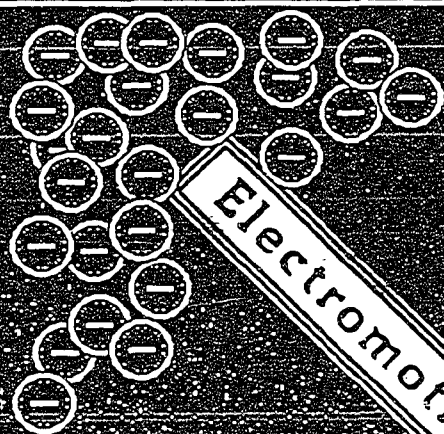
R. I. P.

Always Ready  
Battery

You, too, have probably stated that the batteries are dead when, for example, your flashlight does not work. Given what you have learned about electric circuits, current and electromotive force, explain what you think occurs when a battery is "dead".

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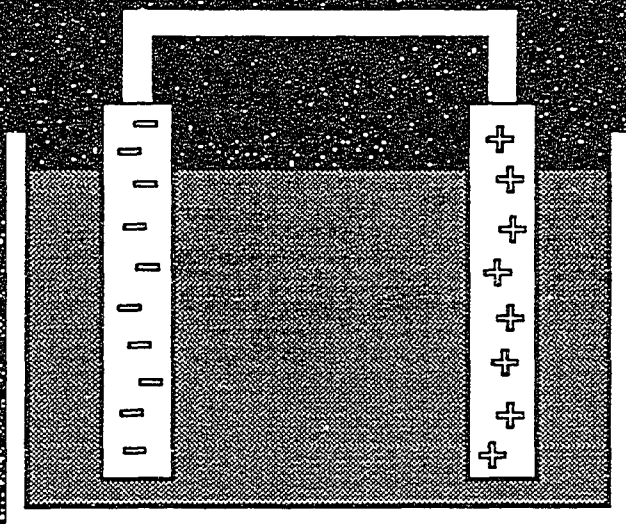
As you may recall from our experience with simple and series circuits, it is the electromotive force (or potential energy) of the battery that causes the electrons to move.

The electromotive force generates the electrical current that passes through each device. The greater the resistance in each device, a greater electromotive force is required to provide current.

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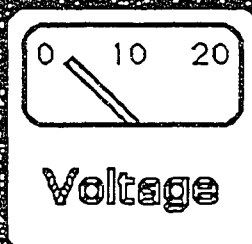
The electromotive force loses some of its strength each time it must provide current. Some of the chemical energy stored in the battery is consumed each time it is used to produce current; and thus, when a battery is "dead" it is because it can no longer produce the excess of electrons in the negative terminal to supply the positive terminal that is lacking electrons.

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**A M E S**

The electromotive force in a battery can be compared to the force that is created in a water tower.



Remember, the electromotive force is measured with a device called a voltmeter. In a circuit, the electromotive force of the battery supplies the "push" to maintain the current. This is a bit like a water tower, which supplies the water pressure to maintain the flow of water in pipes. As the electrical current passes through a device having some resistance, some of the "electrical pressure" or voltage is reduced.

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Voltage reduction can be measured by placing a voltmeter across the device when current is flowing through it. In this circuit, voltmeters have been attached across various devices having different resistances. Which device do you think will require the greatest amount of electromotive force and why? Test your hypothesis by clicking on each voltmeter.

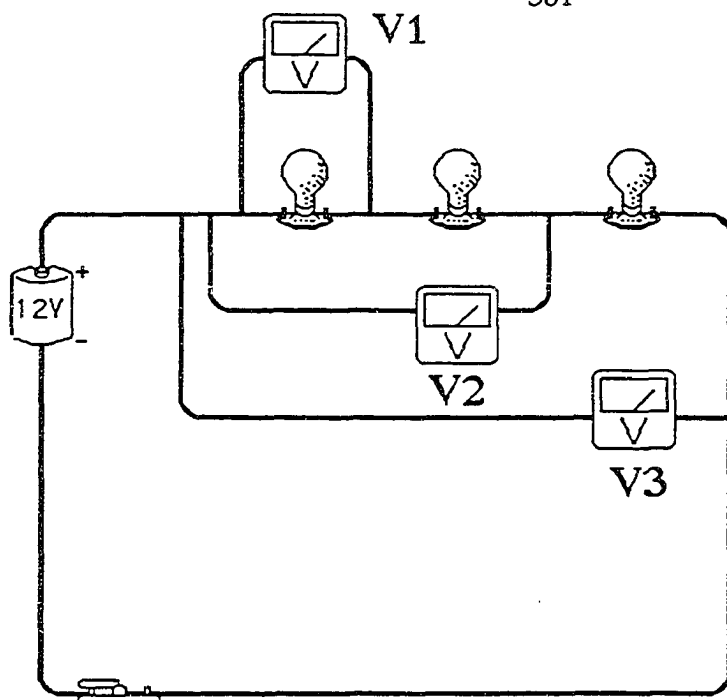
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As you discovered, the toaster required the greatest amount of electromotive force. This means that more electromotive force was required to overcome the resistance of the toaster than was required for each of the other devices.

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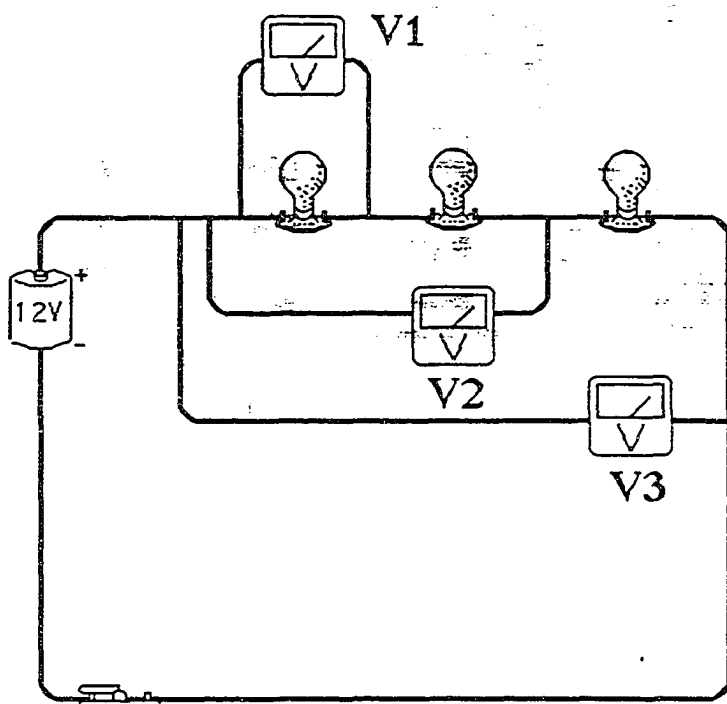


Three voltmeters have been connected to this circuit. Notice that voltmeter 1 (V1) is measuring the voltage across the first device.

Voltmeter 2 (V2) is measuring the voltage across devices 1 and 2, and Voltmeter 3 (V3) is measuring the voltage across all three devices.

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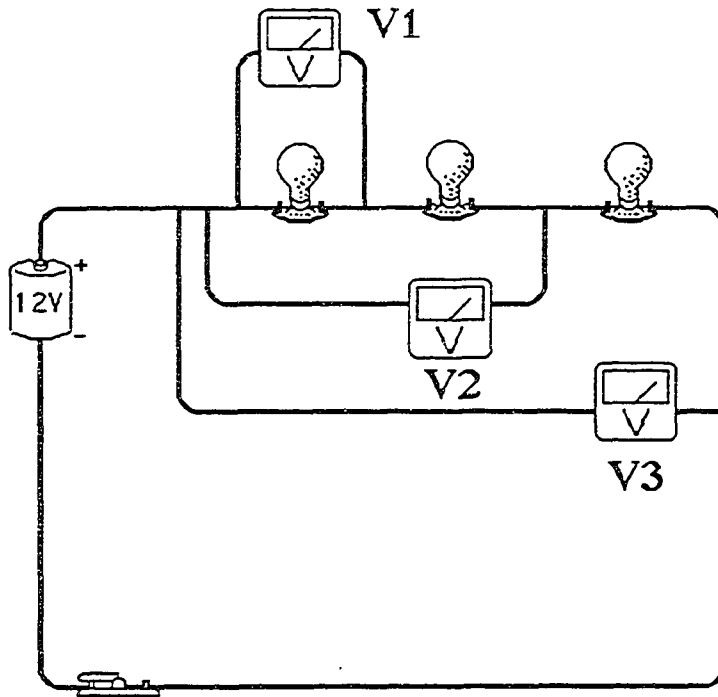
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By clicking on the voltmeters, you will get the voltage reading. Record the readings from each voltmeter. What does the sequence of voltmeter readings tell you about the electromotive force?

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As you measured the voltage across each device, you found that it increased. If we add all the voltage drops in a series circuit, they add up to the total electromotive force of the battery. When a battery is "dead," it is because the electromotive force has been used up. That is, the battery can no longer produce the excess of electrons in the negative terminal to supply the positive terminal that is lacking electrons.

*Go to the Symbol Key*

*Go Back* *Go On*

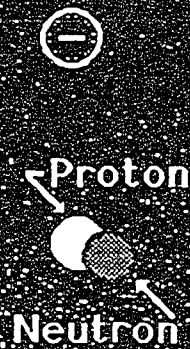
# Summary

Our discussion of electric circuits has provided you with a foundation to explore more complex applications of electrical energy. In this stack we explored the origins of electrical energy, how electrical energy is transferred to devices, basic characteristics of simple and series circuits, and how electrical energy is measured.

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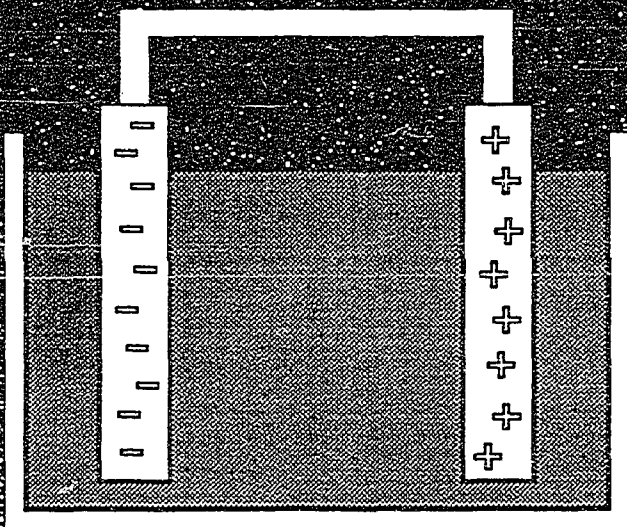




Specifically, you may recall that electrons and protons are electrically charged particles of an atom: an electron is a negatively charged particle and a proton is a positively charged particle.

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To transfer electrical energy, a mechanism must cause the electrons to move. An electrochemical cell produces a chemical reaction that creates the electromotive force which causes electrons to move within a circuit. An electric circuit is a complete path between negative and positive terminals of a power source that allows electrons to move and create a flow of electrical charges. The rate at which electrons move within a circuit is the current.

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# Ohm's Law

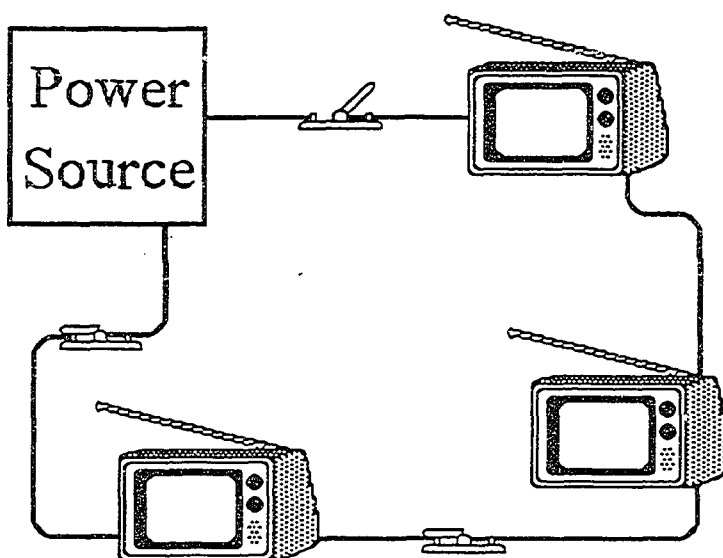
$$I = \frac{V}{R}$$

Ohm's Law explains the relationship that exists among voltage, current, and resistance. Ohm's Law states that the current in a wire is equal to the voltage divided by the resistance.

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# Series Circuits



Series wiring is a method in which several devices can be connected in a single circuit. In a series circuit, multiple devices are connected one after the other and the same current must flow through the entire circuit. In a series circuit, each device receives an equal amount of current, and the current is not consumed.

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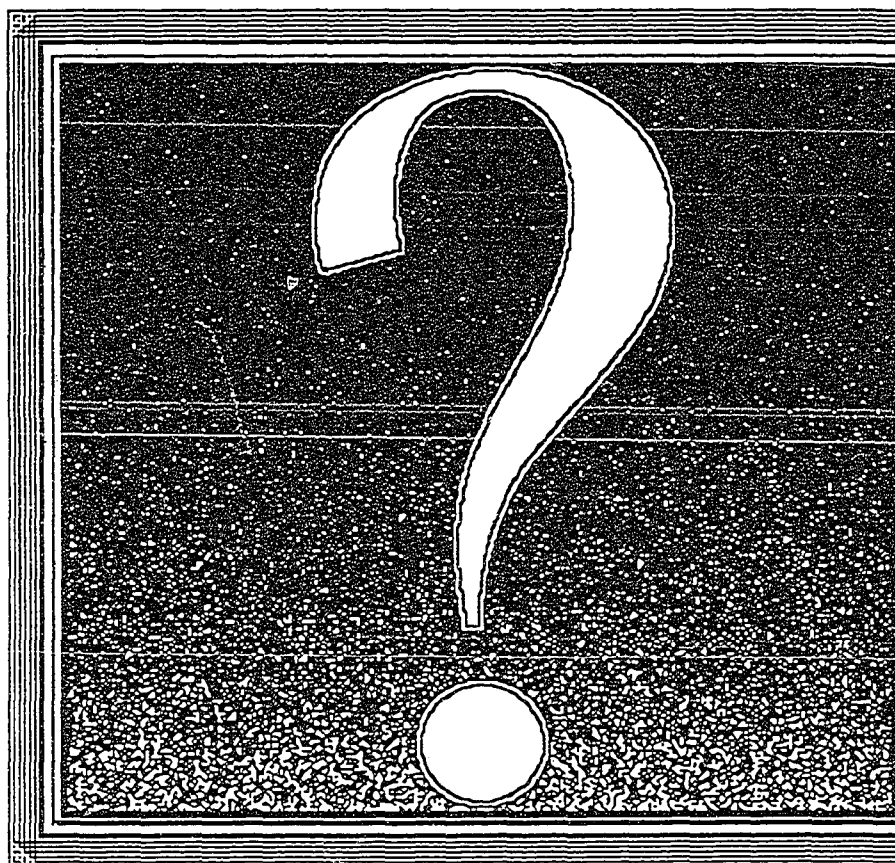
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Finally, some of the chemical energy stored in the battery is consumed each time it is used to produce current. A battery is "dead" when it can no longer produce an excess of electrons to travel from the negative terminal to the positive terminal.

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You will now be given questions that will require you to use the knowledge that you have gained in this stack.

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At this point you may either go back through so that you may review or you may quit this program. If you quit, turn in your materials and pick up your test. You may not review once you quit.

Review

Quit

THANK  
YOU

APPENDIX J. DESCRIPTION OF RANDOM ASSIGNMENT  
PROCEDURES

### **Procedures used to assign students to treatment groups**

Each student in each section was assigned a number; corresponding numbers were placed in an envelope. The researcher drew a number from the envelope and assigned the student with the matching number to the CP treatment. The student with the number that sequentially followed the number drawn from the envelope was assigned to the CCCS treatment. The student with the next number was assigned to the CCCSW treatment, and the student with the following number was assigned to the CCCSWPIG treatment. This process continued until all of the students with the section were assigned to treatment groups.

On the day of the treatment, the instructor directed each student to his/her randomly assigned treatment group. If the numbers of students in the treatment groups were not equal because of student absents, the instructor modified student assignments to make the groups even in number.

APPENDIX K. IOWA STATE UNIVERSITY HUMAN  
SUBJECTS APPROVAL



## Checklist for Attachments and Time Schedule

The following are attached (please check):

12. ☒ Letter or written statement to subjects indicating clearly:
- a) purpose of the research
  - b) the use of any identifier codes (names, #'s), how they will be used, and when they will be removed (see Item 17)
  - c) an estimate of time needed for participation in the research and the place
  - d) if applicable, location of the research activity
  - e) how you will ensure confidentiality
  - f) in a longitudinal study, note when and how you will contact subjects later
  - g) participation is voluntary; nonparticipation will not affect evaluations of the subject
13. ☒ Consent form (if applicable)
14. ☐ Letter of approval for research from cooperating organizations or institutions (if applicable)
15. ☒ Data-gathering instruments

## 16. Anticipated dates for contact with subjects:

First Contact

Last Contact

8/31/92

Month / Day / Year

12/15/92

Month / Day / Year

## 17. If applicable: anticipated date that identifiers will be removed from completed survey instruments and/or audio or visual tapes will be erased:

5/30/93

Month / Day / Year

## 18. Signature of Departmental Executive Officer      Date      Department or Administrative Unit

Ann D. Thompson8/17/92CURRICULUM & INSTRUCTION

## 19. Decision of the University Human Subjects Review Committee:

☒ Project Approved☐ Project Not Approved☐ No Action RequiredPatricia M. Keith

Name of Committee Chairperson

3/18/92

Date

P. M. Keith for P.M.K.

Signature of Committee Chairperson